Chapter 9

Improving the Efficiency of the HIV/AIDS Policy Response: A Guide to Resource Allocation Modeling

James G. Kahn, Lori A. Bollinger, John Stover, and Elliot Marseille

INTRODUCTION

Resources devoted to combating the human immunodeficiency virus and acquired immune deficiency syndrome (HIV/AIDS) have increased dramatically since 2005 (Dieleman and others 2014). However, the rate of increase has slowed in recent years, even though the commitment required to serve all of those in need and to reverse the epidemic has not been reached (Schwärtlander and others 2011; UNAIDS 2013, 2014; WHO 2013). In addition, new recommendations to start treatment earlier in the disease course mean that more resources will be needed than previously estimated. Many of the countries with the highest prevalence of HIV/AIDS have low incomes and carry a heavy burden of other diseases, and it is particularly important to deploy resources judiciously. Finally, efficiency is an even greater imperative in the current era of transition away from funding dominated by international donor aid toward a funding model in which the national governments in affected countries bear a larger portion of the costs; this is especially so since, by some metrics, national governments are failing to increase their own contributions rapidly enough (Resch, Ryckman, and Hecht 2015). Ensuring that available resources are allocated to the most-cost-effective activities is essential to pursuing the aspirational "Getting to Zero" goals of the Joint United Nations Programme on HIV/AIDS (UNAIDS): zero new infections, zero AIDS-related deaths, and zero discrimination. Similar challenges also face global efforts to control tuberculosis and malaria—resources fall short of ambitious prevention and treatment targets.

Various effectiveness, cost-effectiveness, and resource allocation models have been developed to evaluate the costs and outcomes of the choices facing HIV/AIDS policy makers at national and international levels. This chapter presents an overview—including features, uses, and limitations—of the small subset of models that explores the allocation of HIV/AIDS resources across many intervention options and purposes. It does not assess the more numerous models that analyze the cost-effectiveness of one or a few interventions for one purpose. Accordingly, it assesses the set of software tools that portray a wide range of interventions and combinations of interventions in different settings with the goal of providing broad guidance for improved resource allocation.

Corresponding author: James G. Kahn, University of California, San Francisco Institute for Health Policy Studies, San Francisco, California, United States; jgkahn@ucsf.edu.

GENERAL OVERVIEW OF THE ROLE OF MODELS

What Are Models?

Three types of models are relevant to determining the cost-effectiveness of interventions. Epidemic and disease models use mathematics to describe the dynamics of disease acquisition or progression within individuals. Cost-effectiveness models combine epidemic and disease models with a quantitative description of one or more intervention activities typically aimed at altering a specific undesirable event (such as mother-to-child HIV transmission), estimating each intervention's cost and effectiveness in reducing morbidity or mortality. Finally, resource allocation models consider multiple interventions and health events simultaneously and in various configurations to guide the division of effort and funding among different strategies. Often, those disparate health events are translated into a common disease burden metric, disability-adjusted life years (DALYs).[1]

This chapter focuses on the third type, resource allocation models, for several reasons.

- First, in the field of global health, the most useful models for decision makers provide information that is organized and presented to help them choose courses of action that result in better population health outcomes. Resource allocation models are designed explicitly for this purpose.
- Second, they incorporate the two other types of models or practical simplifications of them. For policy makers, it is not essential to understand the individual intervention models because they often examine narrow technical issues that do not contribute meaningfully to more rational resource allocation across multiple interventions.
- Finally, limiting this chapter to resource allocation is practical. Considering the far more numerous epidemic, disease, and cost-effectiveness models and explaining their incompatibilities would be overwhelming for authors and readers alike. Table 9.1 provides a brief comparison of the models reviewed in this chapter.

Strengths and Weaknesses of Models

Resource allocation models, if thoughtfully structured and populated with sound, current data, are able to quantify and logically assemble diverse factors relevant to program decisions in ways that would otherwise be impossible. They highlight and integrate policy-relevant data and dynamics from a complex world, ignoring myriad contextual factors that do not have an important effect on the decision at hand. They can also portray outcomes that are not empirically measurable because of technical or time constraints, such as long-term health outcomes and costs. Finally, they offer a more explicit and rational alternative to other approaches to decision making, such as guesses, inertia, political expedience, or ideology.

The limitations of models reflect the challenge of analyzing a decision with imperfect information. The best models are parsimonious enough to be understandable and buildable, yet adequately realistic to be policy relevant. They are technically sophisticated but easy to use. These competing demands confront modelers with trade-offs that are sometimes difficult to navigate wisely. This is the art of modeling. Despite best efforts, the technical details of models are opaque to all but the most sophisticated users and sometimes even to them. This opacity can be mitigated with clear documentation. Finally, values for the required inputs can be imprecise or biased. For example, efficacy data may be derived from programs in different settings or with modified implementation. To understand the importance of these uncertainties, models rely extensively on sensitivity analyses, that is, assessments of how results change with different input values. Fortunately, the basic findings of models are often robust to input uncertainties.

COMPARISON OF HIV/AIDS RESOURCE ALLOCATION MODELS

HIV/AIDS resource allocation models include the OneHealth Tool, which contains the Goals model and the Resource Needs Model (RNM) by Avenir Health; Optima HIV (part of the suite of Optima models) by the Burnet Institute and the World Bank; the AIDS Epidemic Model (AEM) by the East-West Center; Epidemiological Modeling (EMOD) by the Institute for Disease Modeling; and Global Health Decisions (GHD) by the University of California, San Francisco. Each model is best used as follows:

- *Goals* and *RNM* are widely used and supported by United Nations (UN) agencies and linked with the OneHealth Tool and other disease models for broad health sector planning. The process is moderately intensive, although the models can be adapted to specific purposes in easy-to-use formulations.
- *Optima HIV* is widely used, supported by the World Bank, and consistent with the Goals model. It uses an algorithm to optimize resource allocation across interventions and geography for a given

Table 9.1 Comparison of Models

	Goals, AIDS Impact Model (AIM), and Resource Needs Model (RNM) in Spectrum/OneHealth Tool	Optima HIV	AIDS Epidemic Model (AEM)	Epidemiological Modeling (EMOD)	Global Health Decisions
Institutional home	Avenir Health (www.avenirhealth.org/software-spectrum.php)	Optima Consortium for Decision Science (www.optimamodel.com)	East-West Center (http://www.eastwestcenter.org/research/research-projects/hiv-policy-analysis-research-and-training)	Institute for Disease Modeling (www.idmod.org)	University of California, San Francisco (www.globalhealthdecisions.org)
Disease scope	HIV/AIDS; Spectrum also includes family planning, STIs, tuberculosis, malaria, NCDs, maternal and child health, and OneHealth (health systems).	HIV/AIDS. Optima Consortium has models for TB; malaria; HCV; nutrition; and others.	HIV/AIDS	HIV/AIDS; other EMOD models address tuberculosis, airborne respiratory infections (especially TB), vector-borne diseases (especially malaria), and waterborne diseases (especially polio).	HIV/AIDS
Main use	Widely used across all epidemic types, supported by United Nations agencies; used in partnership with in-country stakeholders to support national strategic planning; linked with OneHealth Tool for broad health sector planning. Automatic optimization of resources across interventions is available. More intensive process for full model, but simplified version is newly available.	Widely used across all epidemic types; in partnership with in-country stakeholders to support national strategic planning. Is one of models supported by World Bank and PEPFAR for use in operations and technical support to governments. Core feature is algorithm to optimize resources across interventions and geography toward strategic objective, subect to specified constraints. More intensive process for full model, but simplified version available.	Used primarily in Asia to model concentrated epidemics; used in partnership with in-country stakeholders to support national strategic planning. Automatic optimization of resources across interventions is available.	Used primarily for research; generalized, concentrated-FSW-based (but not MSM or IDV yet), or mixed epidemics; fully implemented for limited countries. Models MTCT and sexual transmission based on partnership patterns. Simulates impact and cost-effectiveness of scaling-up, targeting, and varied intervention implementation. Automatic user-defined optimization across interventions.	Not widely used at country-level; most appropriate for generalized epidemics. Simplified use and easy interface to explore impact and costs of intervention combinations, implementation scales, and delivery modalities. Manual optimization of resources across interventions.

table continues next page

Table 9.1 Comparison of Models (continued)

	Goals, AIDS Impact Model (AIM), and Resource Needs Model (RNM) in Spectrum/OneHealth Tool	Optima HIV	AIDS Epidemic Model (AEM)	Epidemiological Modeling (EMOD)	Global Health Decisions
Interventions	HIV counseling and testing, linkage to care **Prevention:** Condom promotion/marketing; STI treatment, PMTCT, blood safety, behavior change programs, interventions for high-risk groups (for example, FSW, IDU), voluntary medical male circumcision, PrEP, vaccines **Treatment and support:** antiretroviral therapy, retention in care, opportunistic infection prophylaxis, support to people living with HIV/AIDS				
	Evolving as recommendations change.	Includes interventions listed immediately above and also innovative user-specified interventions, including complementary service modalities, targeted and cross-sectoral interventions, and treatment retention.	Based on user-defined local best-practice prevention packages for key populations (FSW, MSM, PWID, FSW who inject, transgendered populations) and population-specific antiretroviral therapy, which often reflects standard intervention list above.	Targeting by age, gender, location, time, risk, accessibility, sociodemographics. Individual-level variation over time in intervention participation and efficacy.	Subset only.
Geography	National, subnational, or any level for which necessary data are available.		National and subnational.	National, subnational, and smaller. Allows age- and gender-stratified migration between geographic locations and populations.	National, subnational, or any level for which necessary data are available.
Population groups	Adults 15-49 divided into subpopulations by gender, sexual behavior (eg FSW, clients, MSMs), and injecting drug use. Also by HIV disease and treatment status. Perinatally infected children.				
	Standard groups.	Default standard risk and age groups. Users may define unlimited number of population groups as targets of chosen interventions.	Above plus transgender populations. Not children.	Users define groups via traits of individuals, for example, risks (sex behavior, condom use, concurrent partnerships) and health care access (use of ART). Trait intensity can vary by individual within group.	Standard groups.
Time frame	100 years; by year as desired.	Specified by user, by year as desired.	1975 to 2050, by year.	Specified by user; typically monthly or yearly reporting from start of epidemic until 2050.	20 years, by year.
Type of model	**Compartmental deterministic** • Divides population into groups, outcomes reflect movement between groups each time period. • Modest flexibility, low computational requirements.			**Individual stochastic** • Each person is portayed, outcomes reflect random chance of change each time period. • Maximum flexibility, high computational requirements.	**Compartmental deterministic**

table continues next page

Table 9.1 Comparison of Models (continued)

	Goals, AIDS Impact Model (AIM), and Resource Needs Model (RNM) in Spectrum/OneHealth Tool	Optima HIV	AIDS Epidemic Model (AEM)	Epidemiological Modeling (EMOD)	Global Health Decisions
Software	• Data entry and storage: Spectrum software in Windows; data can be copied from other software, for example, Excel. • Parameters are specified within Spectrum. • Calculations within Spectrum.	• Microsoft Excel for data entry with background calculations in Python. • Cloud-based graphical user interface.	• Data entry and storage: Excel 2013 or 2016. • Interventions specified in Excel workbook. • Custom Java interface for user interaction; custom Java code for computation.	• Data entry: JSON or Excel. • Database: COMPS platform (http://comps.idmod.org). • Operation: clickable run file or command line, calculation in C++.	• Data entry: prepopulated, adjust in web interface. • Intevention specified with JAVA graphical web interface. • Computation: Google Go.
User inputs	**Demographics:** (population sizes by age range, gender, major HIV risks; birth & mortality rates); **Disease prevalence:** (HIV, AIDS, STI); **Risk behaviors:** (partnerships, condom use); **HIV program coverage** and **cost**				
	Relevant variables for 7 risk categories. Defaults available for 100 countries.	Flexible population groups defined by user. Defaults available for most countries. If resource allocation analyses then program-related cost functions.	Historical trends for prevalence and behaviors, program effectiveness, and cost by key populations.	Fine detail by age/gender /year. Migration between pairs of geographic locations. Risk and health care access stratification. Health care process flow to define health care intervention access /update/drop-out/re-initiation. Selection of output units and strata.	Default values set for selected countries; calibration available; values modifiable by user. Intevention coverage by delivery model and risk group.
Access	Online (free); training courses are available and support is provided.		Available in conjunction with trainings.	Online (free). Extensive support /collaboration required. Source code (www.github.com /InstituteForDiseaseModeling /EMOD), tutorials and parameters (www.idmod.org /idmdoc), installer (www.idmod .org/software), and database linked to cloud computing resources (http://comps.idmod .org).	Online (free); coordinate with contact person to determine applicability for intended use and request support.
Users	National, local, and international planners (including government), researchers; and monitoring and evaluation officers.			Planners propose model settings and scenarios to be implemented by IDM team or research collaborators.	Planners, researchers, monitoring and evaluation officers.

table continues next page

Table 9.1 Comparison of Models (continued)

	Goals, AIDS Impact Model (AIM), and Resource Needs Model (RNM) in Spectrum/OneHealth Tool	Optima HIV	AIDS Epidemic Model (AEM)	Epidemiological Modeling (EMOD)	Global Health Decisions
Training	Workshops lasting several days.		Normally 3 workshops focused on data needs and collection; preliminary model building; and scenario building for policy and program planning.	Tutorials and demonstration files online, half-day introductory trainings in university classes and conferences; 1-4 weeks of on-site training for detailed projects; and 4-8 weeks to calibrate a new country or setting.	Ten-minute video to use with default values; further guidance required to change input values.
Technical assistance	Minor TA is free, major TA support funded via various mechanisms (UN agencies, bilateral agencies, foundations, national government, and so forth).			By arrangement (free).	By arrangement (free).
Initial set-up time	Default values often available. Otherwise, 3-5 days for data collation and entry.		Normally done as a national process, including extensive review of historical sources of information. As such, generally several months for data collation and trend analysis, then projections and scenarios prepared in about 3 days, normally with vetting by national experts. Updates typically done in less than a week.	Three-hour workshop or webinar; inputs for new setting 2 months; modified inputs for existing setting minutes.	Some default values available. Otherwise, 2-3 days for data collation and entry.
User manuals	Technical documentation: http://avenirhealth.org/software-spectrum.php. Tutorials: https://www.youtube.com/user/spectrummodel	Available at: optimamodel.com/user-guide	Available with training or email request.	• Online at http://idmod.org/idmdoc/—Technical documentation, topic-specific tutorials, parameter definitions, and output file "data dictionary."	Online intro video http://fast.wistia.net/embed/iframe/h08v1rkpvf?wvideo=h08v1rkpvf. No written manual.
Analysis time	Run time 1-3 minutes. Calibration several hours (if needed).		Run time 1-3 minutes. Calibration several days.	Days to months, depending on complexity, from conception of modeling question to results. Some standard analyses run in <1 hour.	Run time < 1 min. Calibration hours.

table continues next page

Table 9.1 **Comparison of Models** (continued)

	Goals, AIDS Impact Model (AIM), and Resource Needs Model (RNM) in Spectrum/OneHealth Tool	Optima HIV	AIDS Epidemic Model (AEM)	Epidemiological Modeling (EMOD)	Global Health Decisions
Outputs	All outputs overall and by population group, by year & cumulative. By intervention scenario. Number in group, deaths, HIV/AIDS new cases and prevalence. Intervention participation; ART prevalence by CD4 count and stage of treatment. DALYs or QALYs. Costs by interventions/care. Cost-effectiveness ratios. Optimal allocations.			Same as Goals and Optima models, plus health care use; relationship and transmission network over time; biomarkers such as CD4. Outputs also available as distributions.	Same as Goals and Optima models.
Sample outputs	Sample outputs are available online at www.avenirhealth.org.	Sample outputs are available online at www.optimamodel .com.	Sample outputs are available online at www.eastwestcenter .org/research/research-projects /hiv-policy-analysis-research-and -training.	Sample input and output files and graphing/analysis scripts available online at www.idmod .org/software.	Sample outputs are available online at www .globalhealthdecisions.org.
Special features	Integrated into OneHealth Tool, permitting cost and impact comparisons across many health sectors; Goals Express offers a simpler version.	Constrained optimization of resource envelopes using algorithms. Flexible group and intervention definition. Modeling of multiple diseases, allowing cost and impact comparison. Optima Lite has simpler preloaded and calibrated projects.	Customized fit of behavioral trends to observed epidemiologic trends by adjusting transmission probabilities and cofactors; use of local data on program effectiveness.	Maximum flexibility to portray individual variation. Users can specify health system and care flow.	User-friendly graphical user interface, direct intervention scenario comparisons.
Limitations	Only one adult age group (15-49) in Goals although outputs are available by five-year age group in AIM.	As with all compartmental models, individual-level data included in aggregated form and homogeneity assumptions apply within specified modeled groups.	Only concentrated epidemics; aggregate age structure based on age pattern of new male and female infections.	Not yet implemented: viral load testing and relationship between VL, age, and survival; evolution and transmission of antiretroviral drug resistance; transmission among MSM and IDU.	No PrEP or vaccines; calibration to countries limited to date. No formal rollout.
Contacts	John Stover (Jstover@AvenirHealth.org)	David Wilson (info @optimamodel.com)	Tim Brown (tim@hawaii.edu)	Anna Bershteyn (abershteyn @idmod.org), Daniel Klein (dklein@idmod.org)	Jim Kahn (jgkahn@gmail.com)

Note: AIDS = acquired immune deficiency syndrome; ART = antiretroviral treatment; DALY = disability-adjusted life year; FSW = female sex worker; HCV = hepatitis C virus; HIV = human immunodeficiency virus; IDM = Institute for Disease Modeling; IDU = injecting drug user; MSM = men who have sex with men; MTCT = mother-to-child transmission; NCD = noncommunicable diseases; PEPFAR = U.S. President's Emergency Plan for AIDS Relief; PMTCT = prevention of mother to child transmission; PrEP = preexposure prophylaxis; PWID = people who inject drugs; QALY = quality-adjusted life year; STI = sexually transmitted infection; TA = technical assistance; TB = tuberculosis; UN = United Nations.

objective, subject to budgetary, logistical, ethical, and political constraints.

- *AEM* is used for studying concentrated epidemics, especially in Asia. The task of calibrating and populating the model is intensive, and exploring the various available packages encourages stakeholders to understand local epidemics and the effectiveness of past, present, and potential future responses.
- *EMOD* is used to examine policy issues involving the interplay of demographics, risks, disease progression, and health care. Individual-based modeling captures heterogeneity and permits a nuanced portrayal—for example, HIV/AIDS transmission is based on independent risk per sex act within partnerships that evolve over time, and disease progression depends on age. Health system dynamics (for example, cycles of antiretroviral use) reflect factors such as age, gender, geography, and risk. Of the models reviewed, it is the most computationally intensive and has the most sophisticated population portrayal and calibration.
- *GHD* is relatively simple to use, with an interface that makes exploring the costs and effects of various combinations of interventions and delivery modalities easy. It is not in widespread use, but is available for appropriate applications by arrangement with the owners. GHD and Optima are exploring a collaboration to incorporate key GHD features into Optima HIV.

The choice of model for a specific user depends on the user's needs and the models' intended uses, strengths, and limitations. As presented in table 9.1, some models are uniquely well suited to specific purposes, such as EMOD for detailed simulation of how individuals' characteristics affect use of health care, and Avenir Health's OneHealth Tool for placing HIV/AIDS programming in the context of the broader health system. When models serve similar purposes, such as Avenir Health's and Optima's resource allocations across HIV/AIDS interventions, users may want to consult the contacts for each model to discuss how comprehensively and efficiently each model can address users' needs. Annex 9A provides a list of country applications for the models.

A more technical comparison and assessment conducted in early 2015 by the HIV Modeling Consortium (HIV Modeling Consortium 2015) was used to inform this review, although it is now slightly outdated because of ongoing model improvements.

Avenir Health Models

Over the past 40 years, Avenir Health, formerly known as the Futures Institute, has led the development of models across many areas of the health sector. Most of these models are assembled within Spectrum, a suite of integrated software models that provides policy makers with an analytical tool to support the decision-making process; it is also widely known by its overlay, the OneHealth Tool. Many of the models also exist as Excel-based models and web-based tools. This chapter focuses on models useful for resource allocation for HIV/AIDS: the AIDS Impact Model (AIM), Goals, and RNM, in particular.

Spectrum is a system of policy models that support analysis, planning, and advocacy for health programs.[2] The models are used to project future needs and examine the effects of policy choices, including the impact of taking actions now rather than later, evaluating the costs and benefits of a particular policy, examining the interrelatedness of different policy decisions, and evaluating how a change in age and sex distribution can affect a wide range of social indicators.

The central impact model in Spectrum is DemProj, which projects the population for an entire country or region by age and gender based on assumptions about fertility, mortality, and migration. A full set of demographic indicators can be displayed for up to 100 years into the future; urban and rural projections can also be prepared. Default data needed to project population are provided from the estimates produced by the Population Division of the United Nations. Models not related to HIV/AIDS include FamPlan, which projects family planning requirements; Resources for the Awareness of Population Impacts on Development, which projects the social and economic consequences of high fertility and rapid population growth; Tuberculosis Impact Model and Estimates, which performs epidemiological and cost-effectiveness analysis of tuberculosis control strategies; Lives Saved Tool, which estimates the cost and impact of scaling up child and maternal health interventions on mortality; and NonCommunicable Diseases, which calculates the impact of scaling up interventions on populations affected by noncommunicable diseases.

The four models related to HIV/AIDS interact with one another. AIM uses the Estimation and Projection Package (EPP) module developed by the East-West Center to fit prevalence and incidence trends to surveillance and survey data and then calculates the consequences of these trends for key indicators such as new infections, deaths, need for treatment, and number of orphans. RNM calculates the costs associated with HIV-related interventions. Goals simulates HIV/AIDS incidence on the basis of behaviors and estimates the epidemiological effects of biomedical interventions and behavioral interventions (using an impact matrix) to calculate infections averted and cost-effectiveness ratios. The Lives Saved Tool evaluates the cost and impact of child and maternal health interventions, including HIV/AIDS and malaria, using inputs from AIM.

AIM

AIM began as a relatively simple Excel-based tool developed in 1991 in collaboration with Family Health International under the AIDS Technical Support and AIDS Control and Prevention projects funded by the U.S. Agency for International Development (USAID). The program has been revised several times since then in collaboration with the UNAIDS Reference Group on Estimates, Models, and Projections. Since 2009, it has been maintained and updated with support from the Bill & Melinda Gates Foundation and UNAIDS. It has evolved to become a comprehensive model within Spectrum used to estimate the impact of the HIV/AIDS epidemic. Several years ago, the Estimation and Projection Package (EPP) was incorporated into Spectrum. Both incidence and prevalence curves are now estimated within AIM, which then projects the consequences of the epidemic, including the number of people living with HIV/AIDS, new infections, and deaths by age and gender, as well as the number of new cases of tuberculosis and the number of orphans. Many of these results are then used in other models in Spectrum. UNAIDS uses AIM to make the national and regional estimates it releases every two years.

The major inputs and outputs of AIM are as follows: Demographic projections are based on user inputs or projections prepared by the United Nations Population Division. The projections start with an estimate and projection of adult HIV/AIDS incidence, which is combined with information on the age and gender distribution of incidence and progression to death to estimate the number of new infections in adults, by age and gender. New infections in infants are estimated from prevalence among pregnant women and the rate of mother-to-child transmission, which is dependent on infant feeding practices and the coverage of prevention with antiretroviral agents. New infections progress to lower CD4 cell counts and are subject to HIV/AIDS-related mortality. Persons who receive first-line antiretroviral therapy (ART), second-line ART, or both live longer than those who do not. People at any stage are subject to other-cause mortality at the same rates as people who are not infected. Adult deaths result in orphans.

In addition to estimating the epidemic and projecting its impacts, AIM has other features, including the ability to validate its estimates by comparing AIM outputs with other data sources, to perform uncertainty analyses for certain output variables, and to aggregate projections, for example, a series of subnational projection files. The model is continuously updated to reflect the most recent research.

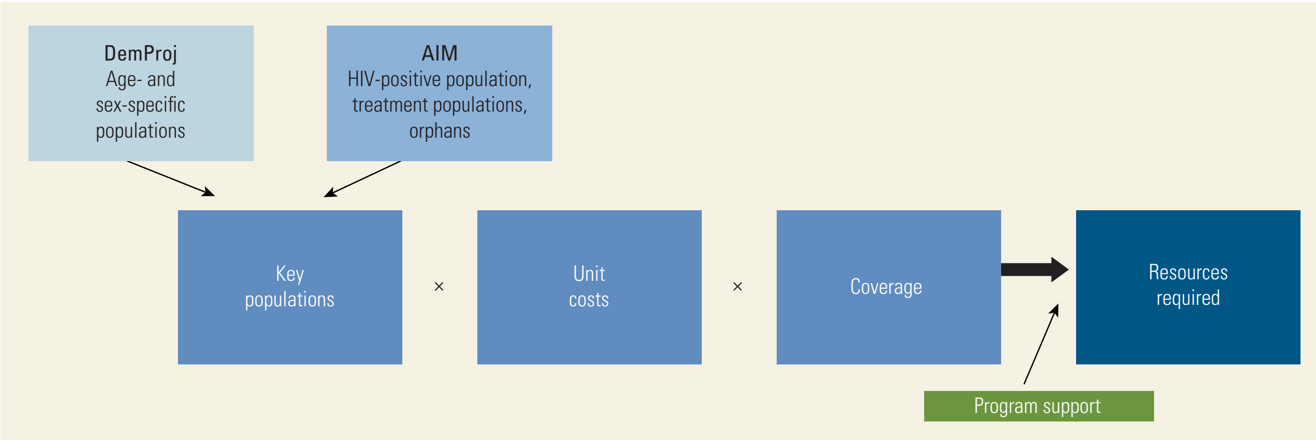
RNM

RNM grew out of efforts developed in 2001 for the first United Nations General Assembly Special Session on HIV/AIDS to estimate the global resources required to combat HIV/AIDS (Schwartländer and others 2001); the estimates are referred to as the Global Resource Needs Estimates (GRNE). Although that first Excel-based model was calculated at the individual country level, it was a global model and not appropriate for country-level use. After the first few rounds of the GRNE, in 2007 UNAIDS initiated a consultative process with countries with high burdens of HIV/AIDS to validate their country-specific portions of the GRNE, which required adapting the global model to the country level. By 2009, the consultative process reached 60 countries, and countries began to use RNM (still in Excel) for their own planning purposes. Because of this, RNM gradually migrated over to Spectrum and now is used to calculate the funding required to expand national responses to HIV/AIDS. It estimates the costs of implementing HIV/AIDS programs, including the costs of care and treatment, prevention, and policy and program support.

RNM projects the costs of various interventions, given assumptions about the size of various population groups, unit costs of interventions, and coverage targets (figure 9.1). Costs can be calculated from any perspective, including provider, public, patient, and societal, depending on the perspective of the data that are provided. A significant portion of the model application process, described in more detail below, involves obtaining reliable cost data. RNM's projections can then be used to enhance knowledge of HIV/AIDS among policy makers and to build support for effective prevention, treatment, care, and mitigation. The projection results are usually transferred to software, such as PowerPoint, for presentation to leadership audiences.

RNM estimates the number of people receiving each service by multiplying the number of people needing the service by the coverage rate (percentage of persons needing the service who actually receive it). The resources needed are then estimated by multiplying the number of people receiving the service by the unit cost of providing it. Before RNM can be used, both a demographic and an HIV/AIDS projection must be prepared. The epidemiology section of AIM calculates the number of HIV/AIDS infections, persons needing treatment, and orphans. This information is used in the treatment section to calculate the costs of treatment for preventing mother-to-child transmission, HIV/AIDS, and associated tuberculosis and opportunistic infections and can be

Figure 9.1 Structure of RNM: DemProj and AIM



Note: AIM = AIDS Impact Model; RNM = Resource Needs Model; DemProj = central model in Spectrum.

used in the mitigation section to calculate the cost of providing services for orphans. AIM modifies the demographic projection through HIV/AIDS deaths and the impact of HIV/AIDS on fertility.

Goals

The Goals model supports efforts to respond to the HIV/AIDS epidemic by showing how the amount and allocation of funding is related to the achievement of national goals, such as the reduction of prevalence and expansion of care and support. It also explores the impact of potential vaccines. The Goals model evolved out of an effort to identify what program managers need to plan effectively. Stover and Bollinger (2002) surveyed 14 national program managers and learned that their most challenging issue was using cost-effectiveness information in their countries' key priority-setting exercise, the National Strategic Plan. The model was developed to be used in that process.

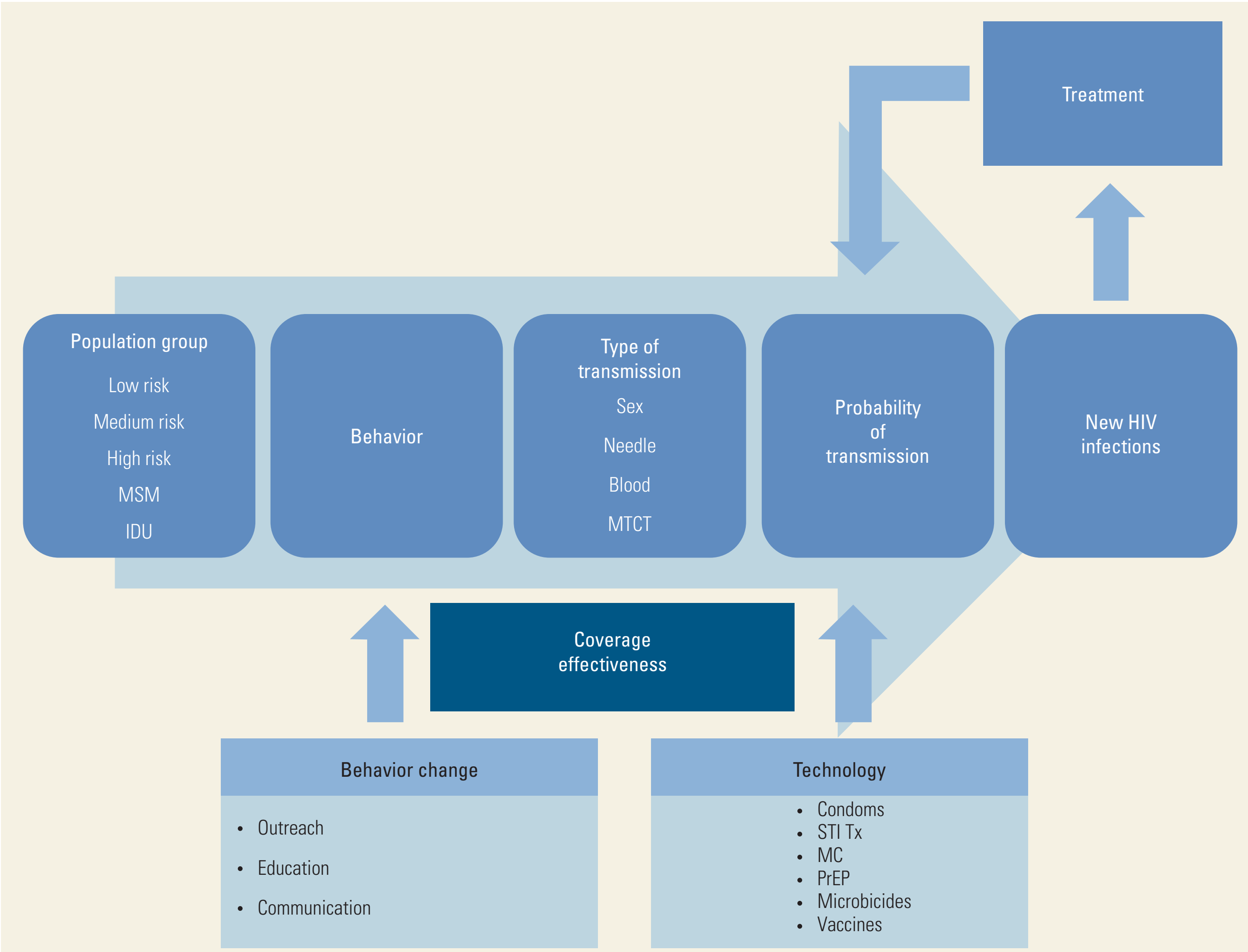
The Goals model is intended to support strategic planning at the national level by providing a tool to link program goals and funding. It can help answer several key questions:

- How much funding is required to achieve the goals of the strategic plan?
- What goals can be achieved with the available resources?
- What effect do alternate patterns of resource allocation have on the achievement of program goals?

The Goals model does not provide all the answers. It is intended to assist planners in understanding the effects of funding levels and allocation patterns on program impact. The model can help planners understand how funding levels and patterns can lead to lower incidence and prevalence and improved coverage of treatment, care, and support programs. It does not calculate the optimum pattern of allocation or recommend a specific allocation of resources between prevention, care, and mitigation, although an optimization routine is available. Sexual mixing is random within risk groups. Mixing between risk groups is limited to low-risk adults who can have partners from higher-risk groups. Extensive literature underlies both the impact matrix coefficients and other model parameters; these sources are well documented in the manual. The Goals model underwent an external validity check comparing 12 mathematical models; results were basically consistent, particularly in the short term (Eaton and others 2013). A recently formed Models for Policy Planning Reference Group, led by the HIV Modelling Consortium (http://www.hivmodelling.org), will be providing ongoing internal and external validity checks.

The Goals model is a compartmentalized model, modeling heterogeneity by dividing the adult population ages 15–49 years by gender and risk group: not sexually active, low-risk stable couples, medium-risk people engaging in casual sex, sex workers and clients, men who have sex with men, and people who inject drugs (figure 9.2). The model calculates new infections by sex and risk group as a function of behaviors and epidemiological factors such as prevalence among partners and stage of infection. The risk of transmission is determined by behaviors (number of partners, number of contacts per partner, and condom use) and biomedical factors (use of antiretroviral agents, male circumcision, prevalence of other sexually transmitted infections). Interventions can change any of these factors and affect the future course of the epidemic. Interventions with either a behavioral or biomedical effect on HIV/AIDS

Figure 9.2 Structure of the Goals Model



Source: Avenir Health. http://avenirhealth.org/software-spectrum.php.
Note: IDU = injecting drug user; MC = male circumcision; MSM = men who have sex with men; MTCT = mother-to-child transmission; PrEP = preexposure prophylaxis; STI Tx = sexually transmitted infection treatment.

transmission are modeled, including behavior change through outreach; education and communication interventions; and biomedical interventions such as condom distribution, voluntary medical male circumcision (VMMC), ART, preexposure prophylaxis, microbicides, and vaccines.

The effect of interventions on behaviors is modeled through an impact matrix that summarizes the impact literature to describe changes in behavior by risk group as a result of exposure to behavior change interventions (Bollinger 2008). The Goals model is then linked to the AIM module in Spectrum to calculate the effects on children (ages 0–14 years) and adults older than age 49 years. The AIM module also includes the effects on pediatric infections of programs to prevent mother-to-child transmission.

The Goals model has been used to assess the impact of prevention and treatment at the global level (Eaton and others 2013; Schwartländer and others 2011; Stover and others 2006) and for more than 30 applications at the country level (see annex 9A for a list of countries).

DMPPT

One of the Excel-based tools developed by Avenir Health is a two-part cost and impact tool available for examining the effects of VMMC; the most recent version of the impact model is called Decision Makers' Program Planning Tool (DMPPT) 2.0 (http://www.malecircumcision.org). The first DMPPT was used to estimate the costs and impact of VMMC in many countries for adult males ages 15–49 years. When experience showed that most VMMC clients were under age 25 years, a second version of the model was developed to evaluate the impact of targeted coverage of VMMC services (Stover and Kripke 2014). This tool is being developed for the web.

OneHealth Tool

The OneHealth Tool is a series of modules overlaid on the impact models of Spectrum. It is intended for medium-term strategic health planning (3–10 years) at the national and subnational levels. The OneHealth Tool was developed by a group of UN agencies, the World Bank, and the World Health Organization (WHO) in response to requests made during a 2008 technical consultation in Senegal by countries looking for standardized costing tools. The model builds on the International Health Partnership and Joint Assessment of National Health Strategies and Plans framework, and experts in costing from all participating UN agencies contributed both fund and staff time to the technical development of the model. The project also received funds from the Global Fund to Fight AIDS, Tuberculosis, and Malaria; the Global Health Workforce Alliance; and the Health Metrics Network, as well as from bilateral development agencies.

The OneHealth Tool was developed because most costing tools at the time took a disease-specific approach rather than a health systems approach (figure 9.3). In addition to covering public sector health interventions at both national and subnational levels, it incorporates coverage of private sector interventions and includes selected nonhealth interventions that may have health impacts. It is a unified tool for planning, costing, impact analysis, and financial space analysis performed jointly and can be implemented at either the health system or program level. The OneHealth Tool provides a way to estimate the cost and impact of interventions for HIV/AIDS, tuberculosis, and malaria simultaneously, as well as other diseases, and to examine the resource requirements from the health system. Default costs from a variety of sources are available, but should be validated and can be subsequently modified by the user. Sources of cost data include the Management Sciences for Health International Drug Price Indicator Guide; the UNAIDS Global Price Reporting Mechanism; Gavi, the Vaccine Alliance; and UNICEF.

The OneHealth Tool includes the following modules:

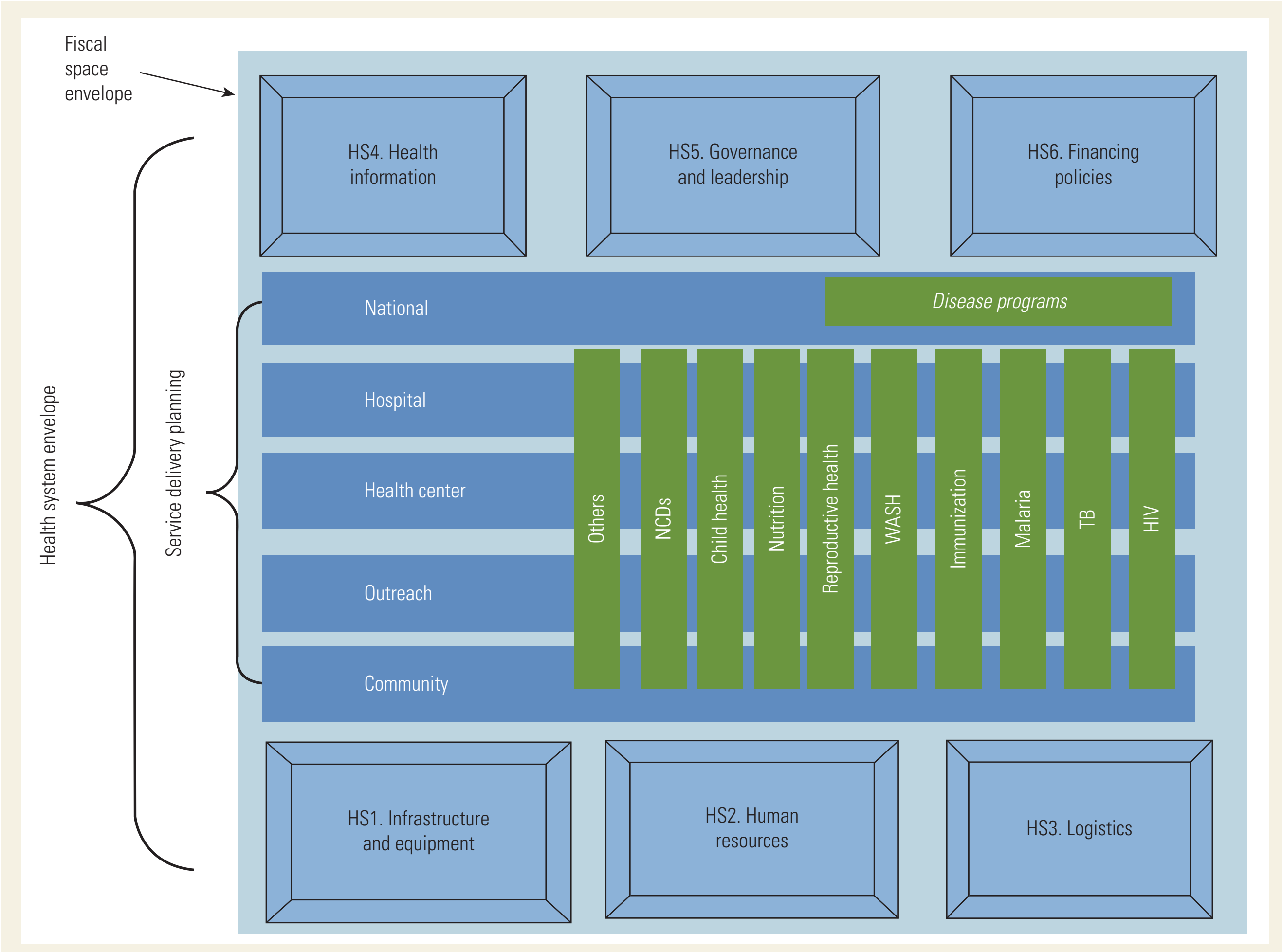
- *Human resources.* The human resources module allows salaries, benefits, and incentives for health service providers and health management and support personnel to be costed, along with preservice training and nonspecific in-service training.
- *Infrastructure.* The infrastructure model deals with planning and costing functions for all facilities providing medical interventions, as well as for most facilities offering support functions. It also includes planning functions for equipment, furniture, vehicles, and communications.
- *Governance.* The governance module includes costing templates for assessing the costs of governance activities.
- *Logistics.* The logistics module allows for the planning of warehouses and vehicles needed to move commodities or drugs and supplies from central warehouses to the endpoints of a logistics system.
- *Health financing.* The health financing module is used to estimate the costs of implementing health financing programs such as vouchers, subsidies, or cash transfers.
- *Health information systems.* The health information systems module includes templates for assessing the costs of implementing a health information system.
- *Budget mapping.* The budget mapping module can be used to allocate intervention and health system costs across budget categories established by the user, to match country or international institution cost categories.
- *Financial space.* The financial space module is used to analyze the financial space, including both public and private health expenditures, within which health plans are expected to be executed.

Optima

Optima HIV is a software package and modeling tool developed by the Optima Consortium for Decision Science in collaboration with the World Bank. It is one of a suite of models for different disease areas that have been developed by the Optima Consortium, all of which are designed to help national decision makers, program managers, and funding partners achieve allocative efficiency and plan for financial sustainability. This is done by applying the Optima approach, a framework for informing public health investment choices that consists of the following core steps:

- ***Assess the burden of disease*** over time, for each population group, and for each disease sequelae or state through data synthesis and epidemiological modeling.
- ***Specify the efficacy and effectiveness of interventions*** (including different modes of delivery) that have the potential to reduce incidence, morbidity, and mortality.
- ***Assess the costs required to deliver services*** at different levels of coverage, including through different service modalities and implementation or efficiency options.

Figure 9.3 Structure of the OneHealth Tool



Source: World Health Organization (http://www.who.int/choice/onehealthtool/OneHealth_Tool_Supporting_integrated_strategic_health_planning.pdf?ua=1).
Note: HIV = human immunodeficiency virus; HS = health system; NCD = noncommunicable diseases; TB = tuberculosis; WASH = Water, Sanitation, and Hygiene for All.

- ***Define strategic objectives and national priority targets*—as well as the *budgetary, logistical, ethical, and political constraints*** related to achieving these objectives—across the entire population and by disease.
- ***Use a formal mathematical optimization algorithm*** around the constructs from the previous steps to assess the optimal allocation of a given level of resources to reduce disease burden, subject to the defined constraints.

Optima HIV is a software package designed to implement the steps listed above. It consists of a mathematical model of disease transmission and progression, a module for defining interventions and cost functions, and a mathematical optimization module that integrates the epidemic, programmatic, and cost data in order to determine an optimal allocation of HIV investments. Optima HIV is the only quantitative tool currently available in the HIV field that includes a formal mathematical optimization routine, real-world budgetary, logistical, and political constraints, and economics of scaling up intervention programs and responses.

Optima HIV is intended to address various policy questions:

- *How close is achievement of the National Strategic Plan targets under current funding?* Over the strategic plan period, how close will the country get to its disease-related targets (a) with the current volume of funding allocated according to current expenditure and (b) with the current volume of funding allocated optimally?
- *How much funding is required to achieve the National Strategic Plan targets?* Over the strategic plan period

or over a longer period, according to current program implementation practices and costs, how much total funding is required to meet the targets, and how is this funding optimally allocated between programs?
- *What benefits can be achieved with more efficient implementation?*
- *What impacts have past programs had?* How would the country's HIV/AIDS trajectory have changed if investment had not occurred in different programs, and what is the estimated cost-effectiveness of the past response?
- *What is the expected future impact of policy or program implementation scenarios?* What is the projected future trajectory of the country's epidemic with and without investment in specific programs or with and without attaining program-specific targets?

Optima HIV extends allocative efficiency analyses to (a) include geographic prioritization and (b) integrate technical efficiency within allocative efficiency, considering the various modalities of service delivery for different programs. As such, it addresses the following questions: Which service delivery modalities and mechanisms should be implemented in which geographic areas? How should the HIV/AIDS response prioritize investment across population groups and geographic areas, and which service delivery modalities and mechanisms should be implemented and to what extent in each area, to get as close as possible to national targets with available resources? Additional descriptions of the uses of Optima HIV for planning a national response are available in chapter 8 of this volume (Wilson and Taaffe 2017).

AIDS Epidemic Model

The AEM, developed in the early 1990s, is patterned after the HIV/AIDS situation in countries with concentrated epidemics, primarily in Asia. It allows countries to build locally tuned models that accurately represent their epidemiological situations. These models can then be used with a set of analytic tools—the AEM workbooks (baseline, intervention, and impact analysis)—to prepare scenarios that analyze alternative responses to the epidemic, assess the impact of these responses, and estimate the cost of implementation.

These scenarios provide essential inputs into national strategic planning processes, help countries allocate their resources more efficiently, and help countries identify weaknesses that must be addressed to strengthen their responses. Using the AEM is an intensive process that builds stakeholder involvement in and ownership of the planning process.

Epidemiological Modeling (EMOD)

The Institute for Disease Modeling[3] developed the EMOD software primarily for use by disease modelers, researchers, epidemiologists, and public health professionals seeking to simulate infectious disease conditions and evaluate the effectiveness of eradication or mitigation approaches. The model is agent based, that is, portraying each individual rather than aggregate group behavior; in discrete time, that is, calculating transmission risk and other processes in small but noncontinuous time steps; and using a Monte Carlo simulator to predict populations, that is, drawing many random samples from a specified probability distribution for each input. This agent-based approach is computationally intensive as opposed to the fast speeds normally achieved with compartmental models (whether dynamic [using differential and integral equations] or in discrete time steps). The advantage is the ability to portray individual characteristics and transitions over time much more precisely. For example, the risk of infection can reflect a large set of person-specific risk factors, such as type of risk behavior and frequency, type of protective behavior and consistency, geographic location, and interactions with other individuals in the same and other risk groups—all of which can and do vary over time. The complex overall EMOD architecture provides disease transmission projections for environmental, sexual, vector-based, and airborne diseases and may be adapted to support additional infectious diseases. The binary software or source files are available for download. Data and training requirements are substantial.

Global Health Decisions

The GHD model was developed by the University of California, San Francisco, to provide an HIV/AIDS resource allocation model with a sophisticated and flexible user interface prepopulated with epidemiologic and programmatic data. The goal was to permit relatively rapid but nuanced allocation of resources across populations and interventions.

A website allows users to specify a country from among those implemented, verify the default input values (for HIV/AIDS prevalence and use of ART, for example), alter the values as needed, and then run a series of tailored intervention scale-up scenarios. The results of each scenario are incidence, prevalence, deaths, and costs, by risk group, over time. These scenario results are stored and can be named and compared graphically.

The back end is a deterministic compartmental model with five risk groups (general population female, general population male, sex workers, drug users, and men who have sex with men), implemented in Google Go. Given a set of predictions for treatment and prevalence in future years, the model uses simulated annealing—a stepwise statistical sampling approach—to align model predictions with these benchmark projections.

The model provides tiered access to functionality, including the use of country-specific defaults for input values (for example, demography, epidemiology, interventions, and costs), real-time adjustment of intervention portfolios, and manipulation of input values by more technically informed users. Policy makers have not used GHD.

WHAT WORKS REVIEWS

A central function of policy modeling is to convey the impact of interventions on health and economic outcomes. This means that resource allocation models need to incorporate the latest evidence on intervention efficacy in changing risks and risk behaviors. Systematic reviews of efficacy are now commonplace, but overwhelming in number and complexity. A distilled review that conveys efficacy and associated strength of evidence can be helpful for informing modeling and educating decision makers about the evidence. Thus, the GHD project initiated an activity called What Works Reviews (WWR) in 2010 to address a perceived gap in the availability of information about intervention efficacy for policy discussions and models.

WWR translates empirical evidence on the effects of interventions into a quantitative synthesis that is technically accurate while being concise and accessible to nontechnical audiences. Each estimate of efficacy is accompanied by a strength-of-evidence rating that reflects the quantity and type of underlying studies. WWR examines both prevention and treatment for each health condition, with a focus on data with the most potential relevance for policy and an emphasis on health outcomes (for example, deaths and disease incidence) rather than process measures (for example, satisfaction with services or adherence).

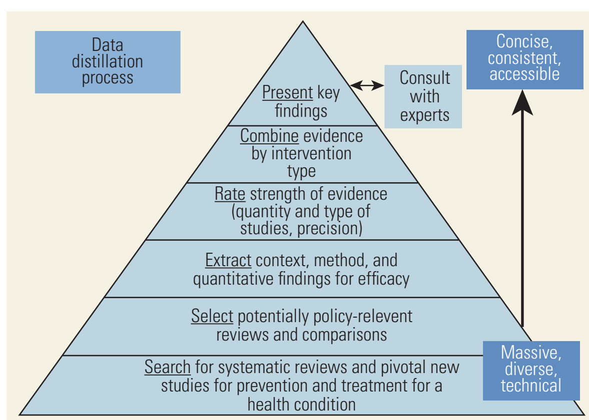
WWR includes nearly 50 categories of interventions for HIV/AIDS, including some found to be ineffective.[4]

Methods

WWR proceeds in explicit and small steps from existing systematic reviews and important new studies to key findings (figure 9.4).

- The first step is to search for systematic reviews and pivotal new studies. Most reviews come from the Cochrane Library, with others identified through PubMed and other sources. The evidence at this level is massive, diverse in form, and technically complex.
- The second step is to select potentially relevant reviews based on whether the information could affect major decisions on policy or funding, such as whether and at what scale to support a particular intervention. Important but narrower questions, such as drug dosing or comparisons between very similar intervention designs, are usually excluded, as are universally accepted practices. All of these decisions are documented.
- The third step is to extract information from the selected comparisons, including context (for example, country and type of population), research methods (for example, study design and outcome measures), and quantitative findings on efficacy.
- The fourth step is to rate the strength of evidence based on the quantity and type of studies, as well as the precision of findings, that is, the width of the relative risk confidence interval. The result is a summary table that presents the intervention comparisons, findings (for example, mortality and incidence), relative risk reduction, and strength of evidence for each review and study.
- The next step, which is critical, is to combine evidence by intervention type where possible. For example, if different insecticides for environmental control of a disease vector (for example, a mosquito) all work with similar efficacy, the findings are combined into a single row. All summary data are linked to original extractions to allow review of the aggregation decisions.
- The last step is to consult with subject area experts to review provisional findings. This step may result in the addition of new reviews or studies or adjustment of the interpretation of existing evidence.

Figure 9.4 Structure of the What Works Reviews Process



Source: What Works Reviews (http://globalhealthdecisions.org/wwr/).

The key outcome is relative risk reduction. This is a standardized metric, designed to put diverse outcome metrics (for example, odds ratio, means) onto a consistent footing (Mirzazadeh, Malekinejad, and Kahn 2015). It equals the percentage reduction in the risk of negative health outcomes and can be used for mortality, morbidity, and indirect health indicators.

Findings are presented in three parts:

- A key findings table has a row for each type of intervention, with the relative risk reduction and strength of evidence for mortality, morbidity, and other indicators.
- An overview reviews the health condition, epidemiology, key findings, and future directions.
- A logic model graphically represents modes of disease acquisition and progression as well as the location of intervention opportunities.

Strength of Evidence

WWR rates strength of evidence on a scale of 0–6 (visually represented by bars). The score is based on the extent and type of studies (for example, randomized controlled trials [RCTs]), quality of available systematic reviews, and precision (that is, narrowness of uncertainty bounds). The following is the typical evidence associated with each score:

6 = three or more RCTs, well reviewed, good precision (very strong)

5 = three or more RCTs, minor problems with review or precision (strong)

4 = two RCTs, good review and precision (moderate strength)

3 = one RCT or multiple non-RCTs, good review and precision (moderate strength)

2 = one RCT or multiple non-RCTs, problems with review or precision (weak)

1 = one or more non-RCTs, serious problems with review or precision (very weak)

0 = no evidence, because of lack of studies or extreme imprecision.

Application to HIV/AIDS

The HIV/AIDS component of WWR was updated with new literature searches and extractions between December 2015 and January 2016. Figure 9.5 presents the logic model for the broad context of HIV/AIDS intervention. Key findings for all intervention types are presented in annex 9B. To illustrate results, this section summarizes the findings for biological prevention strategies.

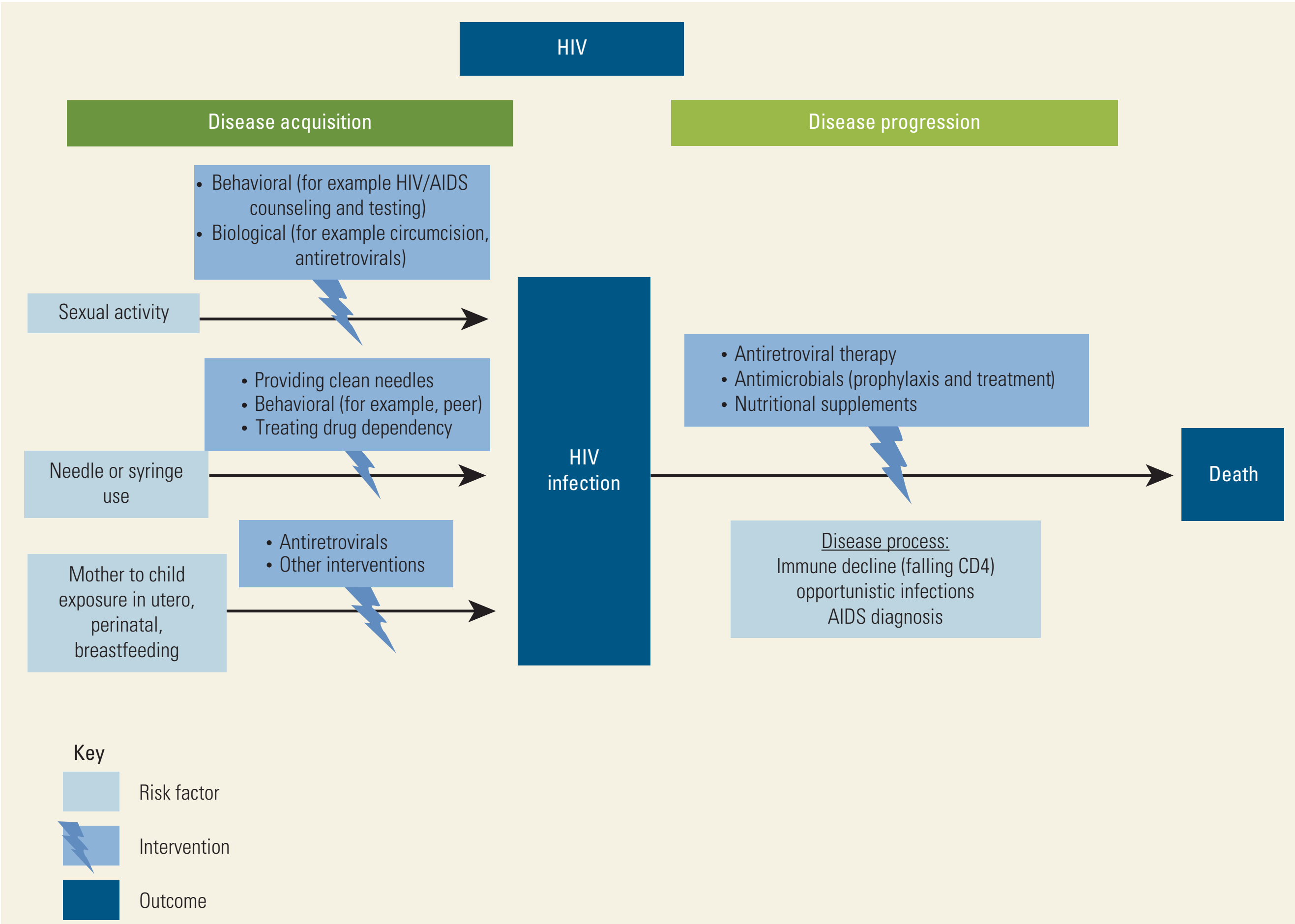
Circumcision of adult males is 70 percent effective in reducing transmission from females to males based on three RCTs, other studies, and long follow-up (very strong evidence). Evidence for men who have sex with men and transgender individuals suggests little if any protection from male circumcision (strong evidence). Treatment of sexually transmitted infections has been examined in eight studies, with a 12 percent non–statistically significant reduction in incidence and a wide confidence interval, including a negative effect (−49 percent to 48 percent), with lower incidence of sexually transmitted infections and risk behaviors (16 percent to 23 percent, moderate strength evidence). Nonoxynol-9 and microbicides failed to reduce HIV/AIDS incidence. Data on microbicides containing an antiretroviral drug suggest a 37 percent reduction in HIV/AIDS incidence (weak evidence). Vaccines did not work, with exception of one trial with 30 percent efficacy, and neither did the latex diaphragm. Preexposure prophylaxis (PreP) with the antiretroviral combination tenofovir plus emtricitabine reduced HIV/AIDS transmission in several RCTs by 47 percent (very strong evidence). Two trials found no effect, due to low sample size and adherence. Use of antiretrovirals reduced incidence by 96 percent in serodiscordant couples in a large RCT in Africa, with similar results from several earlier non-RCTs (strong evidence). The female condom reduced the nonuse of condoms.

FIELD EXPERIENCE WITH MODELS INFLUENCING POLICY DECISIONS

A typical model application associated with developing a National Strategic Plan must be integrated across a number of different dimensions: models used, stakeholders involved, capacity building, and dissemination activities. When an application begins, the first step should be to establish a stakeholder group that will provide input throughout the process. Evaluating the current status of data available is necessary to inform and design the process to be undertaken; some countries may have facility-based costing information for certain interventions, such as HIV/AIDS counseling and testing or ART, but not for other interventions.

The models to be applied then need to be ascertained; many of the models described in this chapter are integral and required in the National Strategic Plan. For the Spectrum models, a country in

Figure 9.5 Logic Model for the HIV/AIDS Component of What Works Reviews



Source: Global Health Decisions (http://globalhealthdecisions.org/wwr/hivaids/hivaids-key-findings/).
Note: HIV/AIDS = human immunodeficiency virus; acquired immune deficiency syndrome.

Sub-Saharan Africa would need to apply the AIM model (to estimate the need for treatment and prevention of mother-to-child-transmission services), the RNM (to estimate the resources required to scale up from current coverage to future levels of desired coverage), and the Goals model (to estimate the impact of various scale-up and resource allocation strategies). The resources required for universal access are compared with an assessment of the resources likely to be available based on National AIDS Spending Assessments, to assess the size of the gap.

Alternative resource allocation strategies can then be developed that prioritize different goals—prevention, treatment, and mitigation. These alternative strategies can be discussed at stakeholder meetings to reach a consensus on the best approach to allocating available resources. The steps include the following:

- Identify and meet with national planning officials and local consultants and perform situation analysis.
- Collect facility-based data and other data.
- Set up models.
- Present initial results to national planning team
- Revise initial analysis, as required.
- Present results to stakeholders and conduct prioritization discussions.
- Prepare the final analysis and report.

Several of the models described in this chapter have been influential in policy making. However, models not only can be influential in changing policy and the policy-making process, but also the interaction of that process can change the models and affect their evolution.

DMPPT

One model that both changed policy and itself was changed through the policy-making process is the DMPPT, developed by the USAID Health Policy Initiative in collaboration with UNAIDS, to inform decision makers about the potential cost and impact of options for scaling up VMMC. When the RCT results for the effect of VMMC on HIV/AIDS transmission were first announced, no publicly accessible, flexible, and supported models were available to estimate the costs and impact of providing VMMC services. In 2007, a large consultative meeting was held by UNAIDS and the WHO, at which consensus was reached to prioritize VMMC in countries with high prevalence of HIV/AIDS and low prevalence of male circumcision (UNAIDS, WHO, and SACEMA Expert Group 2009).

After the model was developed, model applications were performed for 14 Sub-Saharan African countries using readily available data. Based on the results, a series of briefs were written, one for each country and a summary brief for the region as a whole (Njeuhmeli and others 2011). The U.S. President's Emergency Plan for AIDS Relief (PEPFAR) used the briefs heavily to persuade countries either to further investigate the potential cost and impact of VMMC based on primary source data, or simply to adopt a VMMC policy based on the initial results. The briefs were extremely useful in showing the magnitude of those results so clearly.

The original model targeted males ages 15–49 years. Since then, evidence on VMMC began to show that males under age 25 years were most likely to use VMMC services. Because of this finding, a new version of the model, DMPPT 2.0, was developed to estimate the impact of targeting VMMC services by five-year age groups (Stover and Kripke 2014). Several applications of the new DMPPT are under way; new applications of the costing tool are sometimes included to update previous cost estimates based on older technology.

GRNE

Another example of how a model can affect policy is the development and use of the GRNE. The first estimates were developed at the request of UNAIDS to establish a global price tag for the estimated funding required for a comprehensive response to the HIV/AIDS epidemic. Those results were influential in setting the agenda for HIV/AIDS, including the establishment of the Global Fund to Fight AIDS, Tuberculosis, and Malaria.

As both the epidemic and the GRNE evolved, each iteration added various interventions in response to perceived needs. For example, since the original estimates, interventions such as postexposure prophylaxis, safe injection, community mobilization, and prevention for people living with HIV/AIDS were added. Health system considerations began to be included, including health systems strengthening, training, incentives, and infrastructure. A separate effort to estimate the resources needed to support orphans and vulnerable children was spawned and then fed into the existing estimates (Stover and others 2007).

By 2010, the GRNE had expanded to contain many interventions and the total price tag had grown commensurately, while the growth in financial resources had begun to flatten out. In response to these policy issues, the next round of estimates underwent an extensive consultative process to devise a more targeted and strategic approach, identifying interventions that would have relatively higher impact, known as the Investment Framework (Schwartländer and others 2011). Since then, many countries and donors have adopted this approach and developed investment cases to illustrate the validity of the choice of strategy. Throughout this process, models have informed policy making, and the models have evolved and adapted to changes in the policy environment.

AEM

The typical process for the AEM is collaborative. Normally AEM is applied in an in-country process, organized around three initial in-country meetings:

- The first meeting discusses data needs and inputs, how to extract epidemiological and behavioral trends, and sources of data. This meeting is followed by an intensive period of in-country collation of relevant data and extraction of the required AEM inputs.
- The second meeting reviews and uses these extracted trends to build an initial model and then validate it against numerous other data sources, including male/female ratios, results of incidence studies, and early HIV/AIDS trends and more recent ART trends. The resulting model is then normally vetted by various in-country experts, who review both the inputs and outputs and recommend changes where necessary. Based on their input, any required adjustments are made to generate a final national baseline model.

- In the third workshop, key stakeholders are convened to develop scenarios using the intervention and analysis workbooks to explore the epidemic impacts of different resource allocations for prevention and treatment programs, identify differing levels of resource availability, and determine optimal use of available resources under prevailing epidemic conditions.

These workshops are generally held in-country to maximize the engagement of all key stakeholders, ranging from behavioral scientists, epidemiologists, and public health specialists, to program managers, affected communities, and key decision makers. This approach helps increase understanding of what the data are saying about the epidemic, build a common understanding of the forces behind the epidemic, and inform decision makers about which choices will maximize their progress in reversing the epidemic.

Several countries, for example, Bangladesh, Indonesia, Myanmar, and the Philippines, have developed their own in-country AEM teams that work closely with national counterparts to ensure the models produced meet their policy and advocacy needs. AEM helps countries determine where best to focus their prevention dollars to maximize return on investment. Many Asian countries have used AEM as the basis for revising their national plans, to help them in preparing concept notes for the Global Fund, and for national advocacy for more effective responses and expanded resources. In the Philippines, AEM scenarios are being used to actively advocate for expanded HIV/AIDS resources. In Thailand, AEM was instrumental in promoting ART for all by demonstrating substantial downstream savings from removing thresholds for ART access. AEM also formed the basis for the analyses of the Commission on AIDS in Asia, emphasizing the need for responses focused on key populations and high-impact interventions given existing resource constraints rather than trying to cover everybody.

ROLE FOR MULTIPLE MODELS VERSUS CONVERGENCE

With the availability of multiple cost-effectiveness models, often addressing similar policy territory, the issue that arises is the relative merits of multiple models versus convergence on a single model. The following presents some of the advantages and disadvantages of each approach.

- *Complementary substantive areas of focus.* Different models may vary in areas of focus. For example, one model may consider the general features of ART, while another may highlight differences among regimens or monitoring strategies. Thus, policy makers may determine an allocation for ART overall based on one model and allocations for specific activities within an antiretroviral program based on another. The downside is the lack of an integrated assessment and the need to use an extra model. Misalignment of two models may create confusion. If one model considers options A, B, and C, but another model considers B, C, and D, users may become frustrated.
- *Differing level of technical engagement by users.* Some users prefer simpler but less flexible engagement with a model, whereas others prefer more complex and flexible engagement. Policy makers may fall in the former camp, and epidemiologists and other academics may fall in the latter. Although some models offer choice in level of engagement, obviating this distinction, they may excel in either the simpler or the more detailed level of engagement.
- *Competition.* Having multiple models may provide the impetus to improve model design to build a user base through quality improvement.
- *Confirmation and confidence building.* When different models yield substantially similar results, confidence in the validity of the findings is stronger (Hankins, Forsythe, and Njeuhmeli 2011). When results diverge, the attempt to resolve differences can illuminate variations in assumptions or data values that would not otherwise have come under scrutiny.
- *Efficiency*. Perhaps the strongest argument for convergence is efficiency: interested parties can focus efforts on one model, building consensus on methods and inputs. A rigorous review process is essential to provide the quality control that would otherwise arise from competition and comparison.

In 2016, there are two dominant models and other less widely used models. Avenir Health's system of models is widely used in countries and global agencies for policy-making discussions. The Optima HIV model has been used in dozens of countries and for global health agency decisions. Other models are used in more limited settings in specific countries and published in academic journals. They have served many of the quality control functions that might otherwise arise from more balanced competition.

FRONTIERS OF MODELING: WHERE IS ADDED VALUE POSSIBLE?

Unit Cost Resources

All cost-effectiveness models for HIV/AIDS, tuberculosis, and other diseases suffer from a significant gap in required input data—the unit cost of delivering interventions. Although costing studies for many interventions are available, they have several serious limitations: many interventions or important variations in intervention delivery have not been formally costed; many geographic settings are poorly represented in costing studies overall or for specific interventions; and costing methods are inconsistent across studies. The Global Health Cost Consortium, funded by the Bill & Melinda Gates Foundation, is developing a strategy for standardizing existing cost data to improve comparability, extrapolate to new geographic settings, strategically fill gaps in existing data, and improve the efficiency and quality of collecting and analyzing cost data. These data will improve the reach of and confidence in cost-effectiveness models.

Model Comparisons

The multiple HIV/AIDS resource allocation models offer important choices for potential users, with preferences based on the policy questions being examined and the availability of detailed local data. Comparing model results is highly desirable to ensure that estimates are comparable and valid. Comparisons have been made for general predictions, male circumcision (Hankins, Forsythe, and Njeuhmeli 2011), and ART as prevention (Eaton and others 2013) but not for detailed resource allocation issues, despite a comparison of model structure and features (HIV Modelling Consortium 2015). A structured output comparison would be valuable, and may be forthcoming from the HIV Modelling Consortium in late 2016.

External Validity

It has long been recognized that efficacy data collected from research projects, often in atypically well-resourced situations, may not accurately portray the results that could be expected in typical operating programs; the research findings thus have low external validity. However, efforts to describe and enumerate the challenges to external validity vastly outnumber the efforts to improve or even measure external validity. The GHD project has taken initial steps to assess how well research results might be replicated in actual practice settings. Six external indicators were associated with the effect of HIV/AIDS testing on condom use: number of implementation sites, financial incentives, mobile mode of delivering testing and counseling, female sex workers as the target, requirement that clients return to receive test results, and indeterminate or positive HIV/AIDS test results. These results are limited and preliminary, and the analysis needs to be repeated for other interventions. Further progress in developing methods to measure external validity would increase users' knowledge of the accuracy of resource allocation models and their utility as an aid to decision making.

Implementation Approaches

The bulk of massive recent spending on HIV/AIDS services has been vertical: programs focused entirely on prevention, treatment, or care, with no resources for other diseases and largely separate operational structures. Yet various factors highlight the need to consider horizontal implementation: control of the disease, meaning that infected individuals live long enough to experience other illnesses; the ability to identify infected individuals in other service settings, such as reproductive health; and renewed interest in health system strengthening, such as highlighted in *The Lancet* Global Health 2035 Commission on Investing in Health (Jamison and others 2013). Current resource allocation models permit limited examination of implementation approaches, but not comprehensively (the OneHealth Tool comes closest, with explicit consideration of system costs); future modeling would do well to build in more specific options. Analysis of other implementation issues, such as facility- versus community-based service delivery, with or without demand generation, and geographically targeted to high-risk or high-need areas, would be valuable; such analysis is likely to be possible in several of the reviewed models.

Interactions

HIV/AIDS interacts with other diseases in several ways. It co-occurs in certain populations, such as with hepatitis C among persons who inject drugs. The pathophysiologies interact; for example, hepatitis C progression is sped by HIV/AIDS, and CD4 decline accelerates with episodes of malaria. Therapy for HIV/AIDS affects (usually reduces) the risk of other diseases, such as tuberculosis. Capturing these interactions and their potential implications for intervention opportunities and health impact will more accurately portray the relative merits of alternative investment strategies.

Behavioral Economics

Increasingly, behavioral economics—the use of cognitive psychology to influence economically relevant behaviors such as taking risks and seeking care—is gaining traction in health. Cost-effectiveness models can start to incorporate behavioral economics strategies known to be effective. The evidence relevant for infectious and maternal-child disease is in the process of being reviewed by a team at the University of California, San Francisco. In addition, cost-effectiveness analysis can potentially benefit from the insights of behavioral economics. Behavioral economics and its underlying prospect theory note that individuals are more averse to loss than attracted to equivalent gains. Perhaps users of a model will be more influenced if the presentation is framed as *missed* opportunities to avert infections rather than as *new* opportunities to avert infections.

New Cost-Effectiveness Analysis Outcomes

Cost-effectiveness analysis traditionally compares average incremental health impact and cost. It does not consider the effects on financial solvency of high expenditures, nor does it address equity. Extended cost-effectiveness analysis assesses three important considerations for policy makers:

- Household out-of-pocket private expenditures
- Financial risk protection (number of cases of poverty averted)
- Distributional consequences per socioeconomic status or geographic setting (Verguet, Laxminarayan, and Jamison 2014).

An example is provided in *Disease Control Priorities*, third edition, volume 2, chapter 19 on health gains and financial risk protection (Verguet and others 2016).

CONTROVERSIES IN MODELING

The use of models to inform health policy in general and cost-effectiveness models in particular has stimulated debate and controversy.

One of the objections is that cost-effectiveness modeling tacitly reflects ethical judgments about which thoughtful people can disagree. For example, in any comparison of outcomes that uses life years, such as quality--adjusted life years or DALYs, a life-saving intervention will, all else equal, favor younger rather than older people. Most people accept the utilitarian principle on which this rests—as a society, we prefer to save more life years than fewer; others perceive it as a systematic bias against older people. Similarly, and perhaps more controversial, cost-effectiveness analysis puts no greater value on identified lives, such as particular people who are eligible for treatment, than on anonymous, statistical lives that might be saved through, for example, prevention activities. Trading off identified and statistical lives challenges, even offends, the ethical values of some people.

Another area of controversy concerns a central question in cost-effectiveness modeling: the determination of whether an evaluated option is or is not cost-effective, for example, by calculating whether the incremental cost-effectiveness ratio is above or below a threshold. The most widely adopted threshold was initially promoted by the Commission on Macroeconomics and Health and adopted by the WHO and by WHO-CHOICE. This threshold links per capita gross domestic product with returns on investments in health to define the characteristics of cost-effective and very cost-effective interventions (Hutubessy, Chisholm, and Edejer 2003; WHO 2002; WHO-CHOICE 2014).

Many published cost-effectiveness analyses of health interventions in low-resource countries explicitly refer to these WHO criteria as the standard for determining cost-effectiveness. This approach is extremely easy to apply and reflects the fact that willingness to pay for health care depends in part on national income. However, critics argue that these criteria have at least four major limitations:

1. They have little theoretical justification.
2. They skirt the difficult but necessary ranking of the relative values of locally applicable interventions.
3. They omit any consideration of affordability.
4. Finally, the thresholds set such a low bar for cost-effectiveness that very few interventions with evidence of efficacy can be ruled out.

An alternative, if more labor-intensive approach, would be to compare the cost-effectiveness of an intervention being analyzed with the cost-effectiveness of as many locally relevant interventions as possible (Marseille and others 2015).

Other controversies are rooted in methodological concerns. For example, health-state utility is difficult to measure, and results vary for the same disease or condition according to which of a number of accepted methods is used to determine it.

In addition, the related concept of disability weight does not vary by setting for any chosen disease or condition. The disability weights for mobility, visual, or hearing impairment are the same regardless of the economic status of the country or region in which the analyses are being applied. Yet the practical effect on peoples' lives of the same disability is likely to be greater in poorer countries where, for example, roads are more difficult to navigate and fewer aids are available to assist persons with disabilities.

Other concerns pertain to the fact that the data used in models are rarely perfectly suited to the setting or population being studied. Some critics believe that, in view of these and other limitations, undue reliance is placed on the results of models, they are treated as more reliable than they actually are, and they are used to address consequential policy questions for which they are unsuitably designed or parameterized.

CONCLUSIONS

The foregoing tour of HIV/AIDS resource allocation models presents a robust set of options. The models we describe are able to support the flexible examination of the most critical policy questions:

- What will be the cost and health outcomes of investing in different combinations of prevention and treatment interventions?
- How will those outcomes vary according to local factors such as epidemiology, ongoing interventions, and costs?

The models do require some initial setup, although less with the newer streamlined versions than has been the case in the past. More nuanced questions, such as the experience of individuals with particular traits, can be examined, albeit with substantially more investment of effort.

The relative abundance of resource allocation models now available, each with its own particular focus, strengths, and weaknesses, has two sides. Users can choose a model that fits their particular goals and purposes; however, assessing which model is most fit-for-purpose requires more investigation than would be necessary in a world of fewer options. One purpose of this chapter is to serve as a starting point for making such an assessment.

A long-term challenge for models is keeping up with an ever-evolving set of prevention and treatment approaches, and with fine-grained strategies such as micro-targeting of interventions to disease hotspots. The models are constantly improving to reflect these innovations as well as new analytic techniques made possible by enhanced computing power and the advent of "big data" that can help inform model parameters. We believe that resource allocation models will continue to provide up-to-date assistance to HIV/AIDS policy makers, program designers, and other users. Furthermore, the technology is adaptable to health areas outside HIV—some modeling techniques are already being applied to other diseases and more are anticipated.

ANNEXES

The annexes to this chapter are as follows. They are available at http://www.dcp-3.org/infectiousdiseases.

- Annex 9A. List of Countries with Model Applications
- Annex 9B. What Works Reviews

NOTES

World Bank Income Classifications as of July 2014 are as follows, based on estimates of gross national income (GNI) per capita for 2013:

- Low-income countries (LICs) = US$1,045 or less
- Middle-income countries (MICs) are subdivided:
  (a) lower-middle-income = US$1,046 to US$4,125
  (b) upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

1. https://www.youtube.com/watch?v=Exce4gy7aOk.
2. Spectrum was developed with funding from the U.S. Agency for International Development's Health Policy Project, the Bill & Melinda Gates Foundation, Johns Hopkins University, the U.S. Fund for the United Nations Children's Fund, UNAIDS, the World Health Organization, the Global Health Workforce Alliance, and the United Nations Population Fund.
3. See the Institute for Disease Modeling, Bellevue, Washington, at http://idmod.org.
4. WWR can be found at http://globalhealthdecisions.org/wwr/.

REFERENCES

Bollinger, L. A. 2008. "How Can We Calculate the 'E' in 'CEA'?" *AIDS* 22 (Suppl 1): S51–57.

Dieleman, J., C. Graves, T. Templin, E. Johnson, R. Baral, and others. 2014. "Global Health Development Assistance Remained Steady in 2013 but Did Not Align with Recipients' Disease Burden." *Health Affairs* 33: 878–86.

Eaton, J. W., N. A. Menzies, J. Stover, V. Cambiano, L. Chindelevitch, and others. 2013. "Health Benefits, Costs, and Cost-Effectiveness of Earlier Eligibility for Adult Antiretroviral Therapy and Expanded Treatment Coverage: A Combined Analysis of Twelve Mathematical Models." *The Lancet Global Health* 2 (1): 23–34.

Hankins, C., S. Forsythe, and E. Njeuhmeli. 2011. "Voluntary Medical Male Circumcision: An Introduction to the Cost, Impact, and Challenges of Accelerated Scaling Up." *PLoS Medicine* 8 (11): e1001127.

HIV Modelling Consortium. 2015. "Allocative Efficiency Tools and Methods to Support Country HIV Programme Budget Allocation." Imperial College, London.

Hutubessy, R., D. Chisholm, and T. T. Edejer. 2003. "Generalized Cost-Effectiveness Analysis for National-Level Priority-Setting in the Health Sector." *Cost-Effectiveness and Resource Allocation* 1 (1): 8.

Jamison, D. T., L. H. Summers, G. Alleyne, K. J. Arrow, S. Berkley, and others. 2013. "Global Health 2035: A World Converging within a Generation." *The Lancet* 382 (9908): 1898-1955.

Marseille, E., B. Larson, D. S. Kazi, J. G. Kahn, and S. Rosen. 2015. "Thresholds for the Cost-Effectiveness of Interventions: Alternative Approaches." *Bulletin of the World Health Organization* 93: 118–24.

Mirzazadeh, A., M. Malekinejad, and J. G. Khan. 2015. "Relative Risk Reduction Is Useful Metric to Standardize Effect Size for Public Health Interventions for Translational Research." *Journal of Clinical Epidemiology* 68 (3): 317–23.

Njeuhmeli, E., S. Forsythe, J. Reed, M. Opuni, L. Bollinger, and others. 2011. "Voluntary Medical Male Circumcision: Modeling the Impact and Cost of Expanding Male Circumcision for HIV Prevention in Eastern and Southern Africa." *PLoS* 9 (11): e1001132.

Resch, S., T. Ryckman, and R. Hecht. 2015. "Funding AIDS Programmes in the Era of Shared Responsibility: An Analysis of Domestic Spending in 12 Low-Income and Middle-Income Countries." *The Lancet Global Health* 3 (1): e52–61.

Schwartländer, B., J. Stover, T. Hallett, R. Atun, C. Avila, and others. 2011. "Towards an Improved Investment Approach for an Effective Response to HIV/AIDS." *The Lancet* 377 (9782): 2031–41.

Schwartländer, B., J. Stover, N. Walker, L. Bollinger, J. P. Gutierrez, and others. 2001. "Resource Needs for HIV/AIDS." *Science* 292 (5526): 2434–36.

Stover, J., S. Bertozzi, J. P. Gutierrez, N. Walker, K. A. Stanecki, and others. 2006. "The Global Impact of Scaling-up HIV/AIDS Prevention Programs in Low- and Middle-Income Countries." *Science* 311 (5766): 1474–76.

Stover, J., and L. Bollinger. 2002. "Resource Allocation within HIV/AIDS Programs." In *State of the Art: AIDS and Economics,* edited by S. Forsythe. Washington, DC: POLICY Project, Futures Group.

Stover, J., L. Bollinger, N. Walker, and R. Monasch. 2007. "Resource Needs to Support Orphans and Vulnerable Children in Sub-Saharan Africa." *Health Policy and Planning* 22 (1): 21–27.

Stover, J., and K. Kripke. 2014. "Estimating the Effects of Targeting Voluntary Medical Male Circumcision (VMMC) Programs to Different Age Groups: The Decision Makers Program Planning Toolkit (DMPPT 2.0)." Paper presented at the International AIDS Society biannual meeting, Melbourne, July 20–25.

UNAIDS (Joint United Nations Programme on HIV/AIDS). 2013. "Treatment 2015." UNAIDS, Geneva. http://www unaids.org/sites/default/files/media_asset/JC2484_treatment-2015_en_1.pdf.

———. 2014. *Fasttrack: Ending the AIDS Epidemic by 2030*. Geneva, Switzerland: UNAIDS. http://www.unaids.org/sites/default/files/media_asset/JC2686_WAD2014report_en.pdf.

UNAIDS, WHO (World Health Organization), and SACEMA (South African Centre for Epidemiological Modelling and Analysis) Expert Group on Modelling the Impact and Cost of Male Circumcision for HIV Prevention. 2009. "Male Circumcision for HIV Prevention in High HIV Prevalence Settings: What Can Mathematical Modelling Contribute to Informed Decision Making?" *PLoS Medicine* 6 (9): e1000109.

Verguet, S., R. Laxminarayan, and D. T. Jamison. 2014. "Universal Public Finance of Tuberculosis Treatment in India: An Extended Cost-Effectiveness Analysis." *Health Economics* 24: 318–22.

Verguet, S., C. Pecenka, K. A. Johansson, S. T. Memirie, I. K. Friberg, and others. 2016. "Health Gains and Financial Risk Protection Afforded by Treatment and Prevention of Diarrhea and Pneumonia in Ethiopia: An Extended Cost-Effectiveness Analysis." In *Disease Control Priorities* (third edition): Volume 2, *Reproductive, Maternal, Newborn, and Child Health*, edited by R. Black, R. Laxminarayan, M. Temmerman, and N. Walker. Washington, DC: World Bank.

Wilson, D., and J. Taaffe. 2017. "Tailoring the Local HIV/AIDS Response to the Local HIV/AIDS Epidemic." In *Disease Control Priorities* (third edition): Volume 6, *Major Infectious Diseases*, edited by K. K. Holmes, S. Bertozzi, B. R. Bloom, and P. Jha. Washington, DC: World Bank.

WHO (World Health Organization). 2002. *World Health Report 2002: Reducing Risks, Promoting Healthy Life*. Geneva: WHO.

———. 2013. *Consolidated Guidelines on General HIV Care and the Use of Antiretroviral Drugs for Treating and Preventing HIV Infection: Recommendations for a Public Health Approach*. Geneva: WHO. http://www.who.int/hiv/pub/guidelines/arv2013/download/en.

WHO-CHOICE (Choosing Interventions That Are Cost-Effective). 2014. "Cost-Effectiveness Results for Malaria." WHO, Geneva. http://www.who.int/choice/results/mal_afrd/en/.