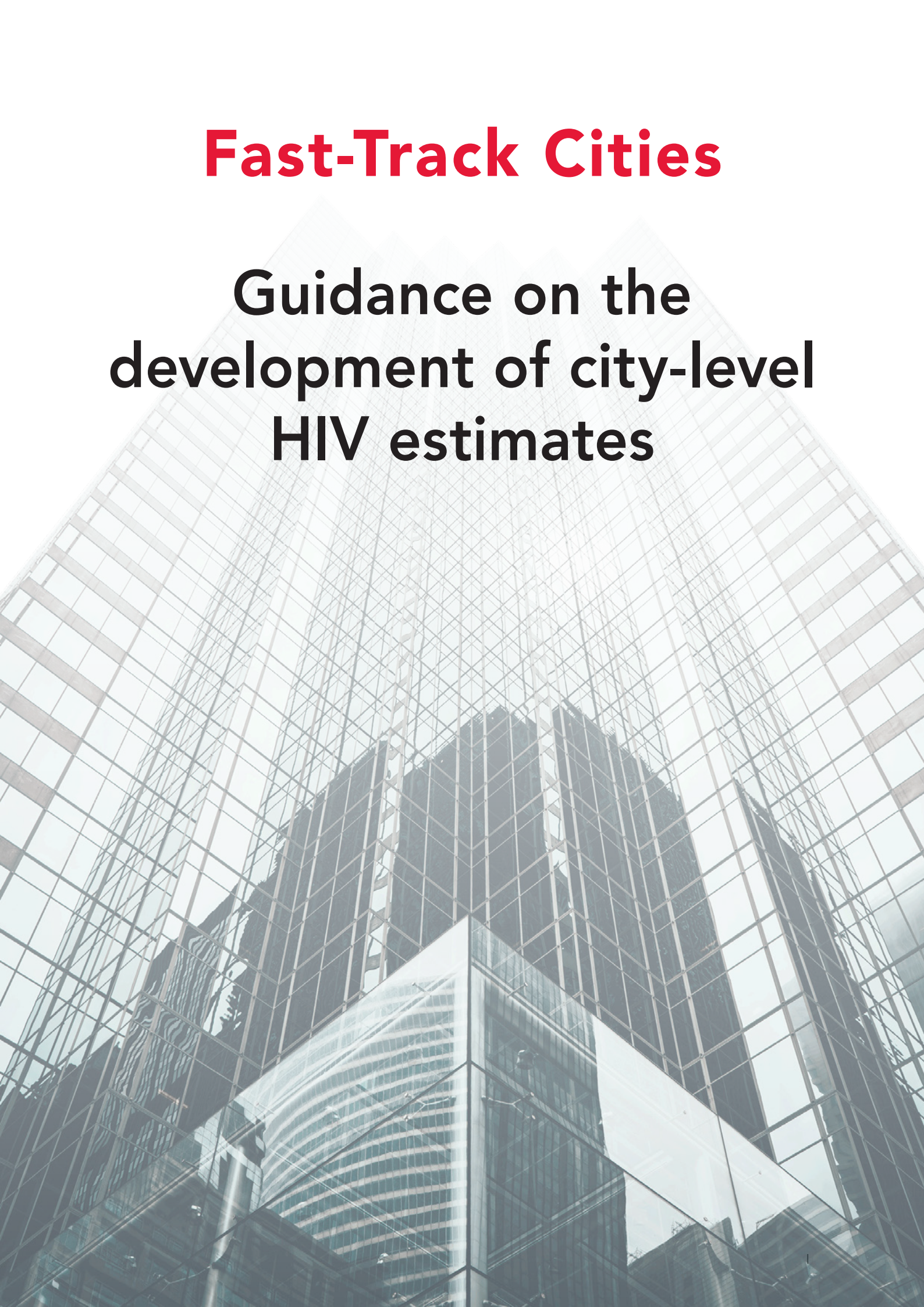
Fast-Track Cities

Guidance on the development of city-level HIV estimates



1. Introduction

Data and strategic information are critical in the HIV response enabling an understanding of the HIV epidemic, the populations and locations most affected, and changes in trends over time. Data and strategic information also help to identify gaps, direct resources, and assess the effectiveness of prevention, treatment, and support programmes. Accurate, timely and comprehensive data on the HIV epidemic and response are therefore essential to inform decision making, programme planning and policy.

There can be considerable geographical variation in HIV prevalence and incidence, even within countries. HIV prevalence and incidence are generally higher in urban compared to rural settings, and cities often account for a substantial proportion of national HIV burdens. Cities can also be home to large numbers of key populations at higher risk of HIV infection. Cities therefore play an important role in meeting national HIV response targets and in ending the HIV epidemic.

In 2014, the Fast-Track Cities initiative was launched in collaboration with the Joint United Nations Programme on HIV/AIDS (UNAIDS), the International Association of Providers of AIDS Care (IAPAC), the United National Human Settlements Programme (UN-Habitat) and the City of Paris. The Paris Declaration on Fast-Track Cities Ending the AIDS epidemic recognises the important role that cities play in accelerating the HIV response and achieving the United Nations Political Declaration goal of ending AIDS as a public health threat by 2030. Cities that sign the Paris Declaration agree to a set of commitments to put cities on the Fast-Track to ending the AIDS epidemic. These commitments include annual reporting on progress in the HIV response and achieving the UNAIDS 95–95–95 targets by 2025—95% of people living with HIV know their HIV status, 95% of people who know their HIV-positive status are accessing treatment and 95% of people on treatment have suppressed viral loads—as well as on the zero stigma and discrimination targets.

Routine monitoring and evaluation of HIV at the city level supports localised responses with tailored interventions, timely identification of emerging trends and effective resource allocation. Understanding the dynamics of HIV epidemics at the city level can lead to the implementation of evidence-informed prevention strategies, improve access to testing and treatment, and ultimately reduce the impact of HIV.

Mathematical models

Mathematical models are essential tools to provide a comprehensive understanding of HIV epidemics. Models provide insights into the complex dynamics of HIV epidemics, enabling a better understanding of patterns of infection, the potential for spread, and informing strategies for prevention, testing and treatment. Mathematical models are a particularly valuable tool for estimating HIV incidence. This is because obtaining direct measurements of incidence can be very challenging and costly. Models can efficiently combine the available data and epidemiological parameters to produce estimates of HIV incidence and trends over time.

The information from models can be used by public health professionals and policymakers to design programmes, estimate service needs and set delivery targets, and tailor resource allocation decisions. Estimates from models can also be used for monitoring trends over time and evaluating progress towards achieving targets and programme impact.

As more data have become available over time, HIV models have adapted to produce estimates at finer geographic levels. This can support more targeted programmes, guide subnational resource allocation, allow for better monitoring and evaluation, and can help to address disparities. Accurate data from reliable surveillance systems are needed to produce robust estimates at these lower levels.

2. Models and tools publicly available for use at the city level

There are several modelling tools publicly available that can be used to produce HIV estimates at the city level. The most suitable modelling approach will depend on the type of surveillance data available and the characteristics of the HIV epidemic. The following tools are open-access applications that can be used to produce city-levels estimates of key epidemic indicators and progress towards UNAIDS 95–95–95 targets:

- Spectrum AIM
  - EPP: Estimation and Projection Package
  - AEM: Asian Epidemic Model
  - CSAVR: Case Surveillance and Vital Registration Tool
- Spectrum District Estimates Tool
- Naomi model, linked to Spectrum
- ECDC HIV Platform Tool
- US CDC CD4 depletion model[1]

Each tool is described below in turn.

Spectrum AIM

Spectrum is a modelling tool used by the majority of countries in the world to develop HIV epidemic estimates, including estimates of the number of people living with HIV, prevalence, incidence, AIDS mortality, rates of mother to child transmission, and progress towards 95–95–95. The AIDS Impact Model (AIM) is the module within Spectrum used to estimate and project HIV epidemic trends over time at the national or subnational level.

Within Spectrum AIM there are several different modelling approaches for estimating incidence including the Estimation and Projection Package (EPP), the Asian Epidemic Model (AEM) and the Case Surveillance and Vital Registration (CSAVR) model. Alternatively, Spectrum AIM can import adult incidence estimated using the ECDC HIV Modelling Tool or from bespoke country models.

EPP

The Estimates and Projection Package (EPP) is a statistical incidence estimation approach available within the Spectrum AIM model. EPP relies on HIV prevalence data over time from routine surveillance and surveys, and estimates HIV transmission rates throughout the epidemic to infer HIV incidence from prevalence data. Incidence is integrated with a demographic model, progression parameters, and programme data to calculate key HIV epidemic indicators over time. Many countries currently use this approach to produce national HIV estimates. EPP can include estimates by key population if prevalence and populations size estimates are available for each key population.

EPP can be used to generate city-level estimates by either creating a city-level sub-epidemic within a national projection file or by creating a standalone city-level Spectrum projection file. The former will utilise existing national demographic projections but will require users to enter city-level population data from Census or national statistics. The latter will require an underlying city-level demographic projection. This can be adapted from the national demographic projection by adjusting the starting population and migration assumptions to match to city population data from Census or national statistics.

1 This model is not publicly available.

AEM

The Asian Epidemic Model (AEM) is a concentrated epidemic model originally developed for use in Asia. AEM is a behavioural process model that simulates HIV transmission, incorporating the dominant patterns of HIV transmission and sexual networks in the region. It includes key populations—male and female sex workers and their clients, men who have sex with men, people who inject drugs, transgender populations—and general population men and women. AEM relies upon HIV prevalence data from key population surveys and combines these with key population size estimates, frequency of sexual and injecting risk behaviours, transmission probabilities, and historic trends in protective behaviours (condom use, clean needles) to estimate new infections over time.

AEM can be used as a standalone application to develop city-level estimates but is normally used in conjunction with Spectrum to ensure the outputs are adjusted appropriately for age and sex. While AEM has extensive input requirements, it provides a detailed picture of transmission dynamics among key populations and with the rest of the population. It also allows exploration of the impacts of programme and policy alternatives.

CSAVR

The Case Surveillance and Vital Registration (CSAVR) model is an incidence estimation approach within the Spectrum AIM module which uses case-based surveillance and vital registration data to estimate HIV incidence trends. This approach is designed for use in settings where routine prevalence data (from sentinel surveillance or routine testing, as in antenatal clinics) are unavailable for most or all years, but high-quality case surveillance and vital registration is ongoing. The CSAVR model is commonly used in middle- and high-income countries with low-level HIV epidemics.

The CSAVR model utilises reported numbers of new adult HIV diagnoses and AIDS-related deaths to estimate trends in new HIV infections and HIV diagnosis rates, accounting for disease progression and the impact of antiretroviral therapy on survival. Incidence estimates produced using the CSAVR model are integrated into Spectrum AIM, and when combined with programme data, produce the full complement of HIV-related estimates and the treatment cascade.

Use of the CSAVR model at the city-level will require developing a separate Spectrum file for each city. An underlying demographic projection is also required but can be adapted from the national demographic projection by adjusting the starting population and migration assumptions to match to city population data from recent census. Both new diagnoses and AIDS-related deaths data are needed at the city-level over the course of the epidemic. The CSAVR model does not currently provide estimates by key population, but this feature is under development.

Spectrum District Estimates Tool

The District Estimates Tool is an additional feature in the Spectrum AIM module. It is used as a simple approach to allocate national (or provincial) estimates for key HIV-related indicators to districts, or any relevant subnational level. The tool uses a finalised national or provincial Spectrum AIM estimation file but then requires users to enter the appropriate district-level data for the population, HIV prevalence, and the number of people receiving ART for a given year. These data inputs are used to disaggregate the national estimates to the district level. Advantages of this approach are its simplicity and transparency, while the sum of the district level estimates equals the official national estimates.

Naomi

The Naomi model is a small-area estimation model used to allocate Spectrum national HIV epidemic indicators down to the subnational levels, typically district level. The Naomi model integrates multiple data sources including national household sero-surveys, geographically disaggregated population data, and routine programme data to estimate the key HIV-related indicators that guide routine monitoring, target setting and resource allocation. These include HIV prevalence, incidence, ART coverage, and estimates of the population currently undiagnosed. The model is implemented in an open-access web-based platform that interacts with Spectrum.

Use of the Naomi model requires a finalised Spectrum AIM estimation file, recent national household sero-survey data, and validated programme data including antenatal clinic (ANC) prevalence, ART coverage at first ANC visit, and numbers of people receiving treatment at the subnational level. For countries that use District Health Information Systems (DHIS), the programme data entry is automated. While the model is predominantly used by countries in sub-Saharan Africa, it can be used in other countries which have prevalence data from a recent national population-based survey (with geocoordinates) and the required programme data.

A new feature of the Naomi model is the inclusion of a correction factor to adjust for people living with HIV (PLHIV) seeking treatment outside their area of residence. For example, PLHIV from neighbouring districts travelling to capital cities to receive treatment, often leading to over-estimation of treatment coverage in the capital city. This allows estimation of gaps in ART service provision based on facility-level attendance. Additional indicators have been added which provide estimates of the treatment cascade that more accurately reflect current service utilisation and unmet need. This approach is recommended for valid HIV treatment cascade estimates in settings with high patient mobility for care.

The Naomi model has been implemented for nearly all countries that have conducted national surveys, with results currently available https://naomi-spectrum.unaids.org/ for the survey year and projections for 2022 and 2023.

ECDC HIV Platform Tool

The European Centre for Disease Prevention and Control (ECDC) HIV Platform is a web-based tool which can be used on or offline to calculate HIV estimates from surveillance data. The HIV Platform combines two previously published applications—the ECDC HIV Modelling Tool and the HIV Estimates Accuracy Tool.

The ECDC HIV Modelling Tool is a back-calculation model which back calculates new adult HIV infections from routinely collected case surveillance data. The model is designed to incorporate the European HIV datasets uploaded to the European Surveillance System (TESSy). The model relies upon case-based surveillance of new HIV diagnoses, AIDS cases, and CD4 count at diagnosis to estimate the number of new infections, time from infection to diagnosis and the size of the undiagnosed population. PLHIV estimates can be calculated using additional data for migration and mortality. Demographic data (sex, age, place of residence) and probable mode of transmission are also captured in TESSy datasets which allows for estimates at the city-level and for key populations.

The HIV Estimates Accuracy Tool is a statistical approach used to adjust the model input data for reporting delays and missing data items, for example missing sex, age, transmission category or CD4 count at diagnosis. This tool is recommended for adjusting case surveillance data prior to entering it into the ECDC HIV Modelling Tool.

US CDC CD4 model

The United States Centers for Disease Control and Prevention (CDC) uses a CD4 depletion model to estimate HIV incidence, prevalence and the diagnosed and undiagnosed population at the national and local levels.

The CD4 depletion model utilises data on new HIV diagnoses and CD4 count at diagnosis to estimate the time from infection to diagnosis. The estimated diagnosis delay is then used to calculate the annual number of new infections, diagnosed and undiagnosed. Estimates of PLHIV are produced by incorporating the cumulative number of deaths from vital registration. This approach can also be combined with modes of transmission data to produce estimates by key population group.

This approach is used to generate the annual national estimates for the United States, it is also used at the sub-national and city level. This model is not currently publicly available.

3. Data Requirements

Producing city-level estimates will require city-level data[2]. For most methods, this will include repeat measures of HIV prevalence or reliable case-based surveillance over time. If key populations are included, repeat measures of HIV prevalence or case-based surveillance throughout the course of the epidemic are required for each key population group. Producing estimates at the city-level will also require consideration of city-level boundaries and mobility in healthcare-seeking behaviours. For example, whether city-level estimates reflect all individuals receiving care in the city in question regardless of official residence, or just city residents. Further guidance will be needed from stakeholders to address this evolving issue.

Estimates for the UNAIDS 95–95–95 targets can be produced across most modelling tools or calculated after city-level HIV epidemic estimates are produced. For the 1st 95, knowledge of status can be estimated using the CSAVR, ECDC, CD4 and Naomi models, calculated from programme data, or applied from national estimates in a *post hoc* calculation. For the 2nd 95, numbers of people on treatment at the city level are required from programme data. For the 3rd 95, estimates of viral suppression require viral load testing data at the city level, or viral suppression can be applied from national estimates in a *post hoc* calculation.

Table 1 details the data requirements, key model outputs, and advantages of the different methods that can be used to produce HIV estimates at the city level. Estimates from the Naomi model are currently available at https://naomi-spectrum.unaids.org/. The District Estimates Tool has the lowest level of data requirements and does not require technical expertise. The use of all other approaches will require previous experience using the tools or technical support.

Technical support may be needed to produce the underlying city-level demographic projections required for standalone city-level Spectrum files. Technical support may be needed for cities opting to use the ECDC HIV Modelling Platform Tool as this platform has recently been updated. Information on technical support can be found in Section 4. Additional resources including websites and methodological publications are listed in Section 5.

2 City stakeholders should agree on the definition of city-level data, for example, whether it is facility-based (regardless of official residency) or residency-based (regardless of the facility where services are provided).

Table 1. Data requirements, outputs, and advantages for estimation methods used to produce city-level HIV estimates

METHOD	DATA REQUIREMENTS
Spectrum District Estimates Tool	▪ National Spectrum file ▪ HIV prevalence: ANC or household survey data for a single year ▪ Population data ▪ Number receiving ART, for a single year
Spectrum EPP model	▪ HIV prevalence data: ANC, survey[3] ▪ Number receiving ART[5] ▪ Population data: Population by urban/rural, geographical area, or key population group ▪ Demographic data: Full underlying demographic projection populated at the city-level
Naomi Model[6]	▪ National Spectrum file ▪ Recent household survey with geocoordinates and subnational HIV prevalence ▪ Area files (GeoJSON) ▪ Routine ANC testing data ▪ Number receiving ART ▪ Population data
AEM	▪ HIV prevalence data by key population[3] ▪ Key population size estimates ▪ Risk behaviours, prevention intervention coverage and STI prevalence by key population group[4] ▪ Number receiving ART[5]
ECDC HIV Modelling Platform	▪ New diagnoses (HIV, HIVAIDS, AIDS) formatted per European surveillance (TESSy) requirements ▪ CD4 at diagnosis ▪ *All-cause deaths among PLHIV (optional, required for PLHIV estimates)*
Spectrum CSAVR model	▪ New diagnoses[5] ▪ AIDS deaths[5] ▪ Number receiving ART[5] ▪ Demographic data: Full underlying demographic projection populated at the city-level
US CDC CD4 model	▪ New diagnoses ▪ CD4 at diagnosis ▪ Mode of transmission ▪ Number of people living with diagnosed HIV in the year prior to new diagnoses data ▪ All-cause deaths among PLHIV

Methods reliant on HIV prevalence data

Methods reliant on case-based surveillance data

Data requirements: All data are required at the city, or relevant subnational level

3 Repeated prevalence measures over time are required from routine testing in ANC or ANC sentinel surveillance. Repeat prevalence from surveys are required for key population estimates.

4 Results available by key population if the model and input data have been structured for key population estimates.

5 Data required over time.

6 Estimates from the Naomi model are currently available at https://naomi-spectrum.unaids.org/

OUTPUTS	ADVANTAGES
▪ PLHIV ▪ New HIV infections ▪ AIDS related deaths ▪ Number receiving ART/ART coverage	▪ Simplest approach ▪ Subnational estimates for all areas sum to national estimates ▪ Available within Spectrum
▪ Prevalence/PLHIV[4] ▪ Incidence/New HIV infections[4] ▪ AIDS related deaths[4] ▪ HIV treatment cascade/95–95–95 *(1st 95 requires external estimate of knowledge of HIV status.)*	▪ Key population estimates can be produced ▪ Full complement of Spectrum results produced
▪ Prevalence/PLHIV ▪ Incidence/new HIV infections ▪ ART (residents): Number/coverage among residents, treatment gap ▪ PLHIV (attending): Number of PLHIV if 100% ART attendance ▪ ART (attending): Number receiving ART at healthcare facilities, treatment gap ▪ Knowledges of HIV status	▪ Synthesis of multiple data sources ▪ Adjustment for mobility in healthcare seeking behaviours ▪ Integration with AIDS Data Repository for DHIS data import and Shiny90 for knowledge of status estimates
▪ HIV epidemic indicators by key population ▪ HIV treatment cascade/95–95–95 *(1st 95 requires external estimate of KOS)*	▪ Particularly applicable to capture transmission dynamics in Asia ▪ Key population estimates ▪ Full complement of Spectrum results can be produced
▪ New HIV infections[4] ▪ Diagnosed and undiagnosed population[4] ▪ PLHIV[4]	▪ Utilises European surveillance datasets ▪ Can adjust for reporting delays, missing data ▪ Key population estimates can be produced ▪ Incidence can be imported into Spectrum for full complement of results ▪ Provides estimates for knowledge of status, including for key populations
▪ Prevalence/PLHIV ▪ Incidence/new HIV infections ▪ AIDS related deaths ▪ HIV treatment cascade/95–95–95	▪ Utilises routine case surveillance data ▪ Full complement of Spectrum results produced for all years ▪ Knowledge of status can be estimated within CSAVR, or entered from programme data
▪ Incidence/new HIV infections[4] ▪ Diagnosed and undiagnosed population[4] ▪ Prevalence/PLHIV[4]	▪ Key population estimates can be produced ▪ Model inputs are adjusted for missing data and reporting delays ▪ Input data only required for the recent period, not for the entire historical trajectory

4. Technical support

Spectrum AIM—EPP and CSAVR

- Spectrum model available at https://www.avenirhealth.org/software-spectrum.php
- Technical support: https://support.avenirhealth.org/hc/en-us
- User guide available at: https://hivtools.unaids.org/hiv-estimates-training-material-en/, *73D Guide for Updating Spectrum Estimates*

Naomi Model

- Model available at https://naomi.unaids.org
- Technical support: naomi-support@imperial.ac.uk
- Naomi HIV sub-national results viewer: https://naomi-spectrum.unaids.org/
- User Guide

AEM

- Tutorial: https://hivtools.unaids.org/hiv-estimates-training-material-en/, *21D Basic Steps to Update AEM*
- Technical support: Tim Brown, tim@hawaii.edu
- User guide
- Analysis and advocacy guidelines

ECDC HIV Modelling Platform

- Model available at https://shinyapps.ecdc.europa.eu/shiny/hivPlatform/
- Technical support: HIV.Modelling@ecdc.europa.eu
- User Guide

US CDC CD4 model

- Model not publicly available
- Technical support: *to be confirmed*
- Additional information

UNAIDS

- UNAIDS HIV Estimates Training Materials: Modelling guidance documents and PowerPoint presentations, https://hivtools.unaids.org/hiv-estimates-training-material-en/
- Fast Track Cities contact: Eleanor Gouws, gouwse@unaids.org

IAPAC/FTCI

- IAPAC/Fast-Track Cities institute contact: Sindhu Ravishankar, sravishankar@ftcinstitute.org

5. Additional Resources

Websites:

- Global Web Portal: https://www.fast-trackcities.org/
- UNAIDS Fast Track Cities: https://www.unaids.org/en/cities
- IAPAC Fast Track Cities: https://www.iapac.org/fast-track-cities/

Methodology publications:

- Spectrum EPP
  - Stover J, Glaubius R, Kassanjee R, Dugdale CM. Updates to the Spectrum/AIM model for the UNAIDS 2020 HIV estimates. *JIAS*. 2021; 24(S5). https://onlinelibrary.wiley.com/doi/10.1002/jia2.25778
  - Stover J, Glaubius R, Mofenson L, *et al*. Updates to the Spectrum/AIM model for estimating key HIV indicators at national and subnational levels. *AIDS*. 2019; 33 (Suppl3): S213-226. https://pubmed.ncbi.nlm.nih.gov/31805028/
- Spectrum CSAVR
  - Mahiane SG, Marsh K, Glaubius R, Eaton JW. Estimating and projecting the number of new HIV diagnoses and incidence in Spectrum's case surveillance and vital registration tool. *AIDS*. 2019;33(Suppl 3):S245–53. https://pubmed.ncbi.nlm.nih.gov/31385865/
  - Mahiane SG, Eaton JW, Glaubius R, *et al*. Updates to Spectrum's case surveillance and vital registration tool for HIV estimates and projections. *JIAS*. 2021; 24(S5). https://pubmed.ncbi.nlm.nih.gov/34546641/
- AEM
  - Brown T, Peerapatanapokin W. The Asian Epidemic Model: a process model for exploring HIV policy and programme alternatives in Asia. *Sexually Transmitted Infections*. 2004;80:i19-i24.
  - https://hivtools.unaids.org/hiv-estimates-training-material-en/, *40A Under the hood: AEM*
- Naomi
  - Eaton J, Dwyer-Lindgren L, Gutreuter S, *et al*. Naomi: a new modelling tool for estimating the HIV epidemic indicators at the district level in sub-Saharan Africa. *JIAS*. 2021; 24(S5). https://onlinelibrary.wiley.com/doi/10.1002/jia2.25788
  - Esra R, Mmelesi M, Ketlogetswe A, *et al*. Improved indicators for subnational unmet antiretroviral treatment (ART) need in the health system: updates to the Naomi model in 2023. *JAIDS*. 2023 [submitted].
- ECDC HIV Platform Tool
  - van Sighem A, Nakagawa F, De Angelis D, *et al*. Estimating HIV incidence, time to diagnosis, and the undiagnosed HIV epidemic using routine surveillance data. *Epidemiology*. 2015;26*(5)*:653-60. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4521901/
  - Rosinska M, Pantazis N, Janiec J, *et al*. Potential adjustment methodology for missing data and reporting delay in the HIV Surveillance System, European Union/European Economic Area. 2015. *EuroSurveillance*. 2018; 23*(23)*.
- US CDC CD4 model
  - Song R, Hall HI, Green TA, Szwarcwald CL, Pantazis N. Using CD4 Data to Estimate HIV Incidence, Prevalence, and Percent of Undiagnosed Infections in the United States. *J Acquir Immune Defic Syndr*. 2017;74*(1)*:3–9.

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