
Technical Refinements for Spectrum 2013: December 2012

Report and recommendations from a meeting of the UNAIDS Reference
Group on Estimates, Modelling and Projections held in Geneva,
Switzerland, 6 December 2012

REPORT & RECOMMENDATIONS



The meeting of the UNAIDS Reference Group on Estimates, Modelling and Projections was organised for UNAIDS by the secretariat of the Reference Group (www.epidem.org) based at Imperial College London. Participants of the meeting are listed at the end of this document.

Kelsey Case, January 2013

Introduction

The Joint United Nations Programme on HIV/AIDS (UNAIDS) *Reference Group on Estimates, Modelling and Projections* exists to provide impartial scientific advice to UNAIDS, the World Health Organization (WHO) and other partner organisations on global estimates and projections of the prevalence, incidence and impact of HIV/AIDS. The Reference Group acts as an 'open cohort' of epidemiologists, demographers, statisticians, and public health experts. It is able to provide timely advice and also address ongoing concerns through both *ad hoc* and regular meetings. The group is co-ordinated by a secretariat based in the Department of Infectious Disease Epidemiology, Imperial College London.

Aim of the meeting

To finalise the changes needed in Spectrum in advance of the start of the new estimation cycle for the UNAIDS 2013 Global Estimates.

The specific objectives of this meeting were:

- 1) To review the results from systematic testing and comparison conducted on the two revised approaches proposed for curve fitting – r trend and spline – which will replace the variable r method currently in the Estimation and Projection Package (EPP) component of Spectrum.
- 2) To review new data and analyses available to inform the methods and parameters to be used in Spectrum 2013.

Approach

The meeting featured presentations combined with group discussion to generate consensus recommendations. The meeting agenda is included in Appendix I and the list of participants is included in Appendix II.

The recommendations drafted at Reference Group meetings give UNAIDS and WHO guidance on how best to produce estimates of HIV/AIDS, provides an opportunity to review current approaches and also helps to identify information needs (earlier reports are published on the Reference Group website www.epidem.org). This transparent process aims to allow the statistics and reports published by UNAIDS and WHO to be informed by impartial, scientific peer review.

1. Estimation and Projection Package (EPP)

1.1 Status update and new features

The new models — Le Bao's 7-parameter r-trend and Dan Hogan's hybrid spline approach — have been fully implemented in EPP. These models perform faster than variable-r (but still take time). As countries move to the use of a new model, it is to be expected that national projections will also change. The move from the use of maximum likelihoods to Bayesian medians may also result in changes to the projections thus it will be extremely important that countries compare their previously obtained fits to the current fits obtained, at an early stage in the estimation process. It is also important that more care is taken, particularly for data-scarce countries or sub-populations, to ensure that the curves generated and the projections obtained are realistic. In order to aid this process, a new *compare* tab has been added to the EPP results page which allows prevalence, incidence and the size of sub-populations to be compared with a previous SPT file.

A *validate* tab has also been added which illustrates the projection file compared to other data sources available. This includes reported AIDS diagnoses populated automatically from the WHO system up to 2001 (currently) juxtaposed by AIDS deaths, and reported HIV cases juxtaposed by new incident infections. Countries can also populate the data sources tables with their own data. This section may be a particularly useful resource for concentrated epidemics with very good data. However, it was discussed that this section requires very good knowledge of what is occurring on the ground and it is important to ensure that biases are not validated (for example, the use of MoT results will be a circular process) .

Recommendations

- ✓ **Scale the viewer display for easier comparison.**
- ✓ **Off-set AIDS deaths by one year in order to compare with reported AIDS cases.**
- ✓ **Truncate AIDS cases with the onset of treatment (possibly later for concentrated epidemics); do not truncate reported HIV cases.**
- ✓ **Rename the "validate" tab (too strong).**
- ✓ **Generate a guidance document for the use and interpretation of the *validate* and *compare* sections.**
- ✓ **Validate EPP mortality with Spectrum mortality in a sample of countries to ensure that they are in agreement.**
- ✓ **In EPP, only allow users to change the final year of the projection, do not allow changes to the initial year.**

Follow-up: EPP team to make all modifications, completion by Jan, 2013

1.2 Refining EPP calibration to population-based surveys: incorporating trends & non-participation, *Dan Hogan*

Incorporating survey trends in the likelihood calculation

The current post-fitting calibration approach in EPP can miss trends in prevalence suggested by national population-based surveys. As more countries increasingly have data from two or more national surveys, it becomes even more important to include these trends in the fitting procedure.

Dan Hogan has proposed a method to incorporate these trends (using an estimation of the calibration constant) into the fitting procedure. This method can be used with r-spline, r-trend and r-flex methods, appears better able to capture the trends and level of population-based survey data, and gives better uncertainty. However; as currently implemented, this method requires longer fitting time (2-3 times as long).

Recommendations:

- ✓ **Dan to provide code for the EPP team.**
- ✓ **Dan, Jeff and Le to review implementation and further work on these methods, testing in situations where trends in survey and ANC data vary (Kenya, South Africa).**

Follow-up: Dan, Jeff, Le to continue this work for review Jan 2013

Including uncertainty around HIV prevalence estimates from population-based surveys due to non-participation

Due to the importance of non-response bias, current estimates of HIV prevalence from population-based surveys may not be as precise and previously considered. If possible, it would be beneficial to incorporate the inflated uncertainty around prevalence estimates from these surveys using a simple function. Dan Hogan compared standard errors for complete case and Heckman-type selection model estimates of HIV prevalence for men and women across 12 surveys and predicted Heckman standard errors with a linear model using variables easy to obtain (complete case prevalence rate and participation rate). A comparison of the standard error, found fairly high correlation (around 0.8) and reasonable predictive power of the Heckman standard error vs key variables. Looking at extreme values (to identify how the model works if the extreme situation gets observed) resulted in 5 times higher standard error compared to the complete case standard error. This approach would result in a massive increase in uncertainty. To pursue this approach, the predicted standard error could be reduced by a factor of 2 (bootstrap compared to parametric simulation 95% CI).

Recommendations:

- ✓ **Look at uncertainty together with the inclusion of surveys in the likelihood to fully understand what impact these have together on model fits.**
- ✓ **Conduct this work by urban/rural in order to fully understand the impact of this implementation.**

Follow-up: Dan and Jeff to continue this work for review Jan 2013

1.3 Model Evaluation

In order to objectively and systematically evaluate the performance of two methods for fitting in EPP, formal evaluation criteria was defined (Appendix III) and blinded testing was conducted. Results from this process indicated both models performed well for the in-sample fit and that the main differences were in the incidence projections. Overall, it was identified Model 1 (r-spline) performed better, in general; however, Model 2 (r-trend) was better able to capture difficult situations (up-tick in prevalence) in countries with very high amounts of data. It was also noted that r-spline takes more time to run than r-trend.

Recommendations:

- ✓ For generalised epidemics, r-spline is the recommended default method for fitting in EPP. For countries that are fitting with very large amounts of data or trying to capture difficult trends in data-rich situations (e.g. up-ticks in prevalence), r-trend is recommended.
Follow-up: UNAIDS to incorporate into guidance documents, Feb 2013
- ✓ For concentrated epidemics, if there is zero structure and very limited data, EPP classic should be used for fitting. If there are adequate data available, r-spline can be used for fitting.
Follow-up: UNAIDS to incorporate into guidance documents, Feb 2013
- ✓ All models should be kept in EPP but those that are not being used will be “turned off” on the user interface.
Follow-up: EPP team to modify user interface, Feb 2013
- ✓ Additional testing should occur to confirm the recommendations above.
Follow-up: UNAIDS to incorporate into guidance documents, Feb 2013

2. Spectrum

Review and discussion of new assumptions for parameters in Spectrum

Validation

A validation menu is also available in Spectrum with outputs for prevalence by age and sex, adult mortality (pre-populated with raw survey data from UNPOP but countries can also add their own inputs), adult ART, PMTCT, under 5 mortality rate, child ART.

UN Population Division interface update

For high prevalence countries, UNPOP Division will continue to produce the non-AIDS mortality (as they have in the past), using Spectrum estimates of AIDS deaths. For the few countries with very good mortality data, UN Pop Division will produce all-cause mortality and Spectrum will construct the age-specific mortality rate adjustment. There are 6-7 countries that fall into this category. For all other countries, UN Pop Division will produce all-cause mortality, Spectrum will vary life expectancy at birth, non-AIDS mortality will be based on the model life table and Spectrum will iterate to find the AIDS mortality.

Recommendations:

- ✓ **Continue to prepare Spectrum for the new UN Population Division data to ensure the smoothest transition possible.**
Follow-up: Futures Institute, UN Pop Division, ongoing
- ✓ **Basia Zaba to communicate with UN Pop Division to identify the potential usefulness of the ALPHA Network life tables from uninfected individuals.**
Follow-up: Basia Zaba, Dec 2013

PMTCT

Spectrum has a revised PMTCT editor and new PMTCT outputs. The new editor has not explicitly included an input line for Option B+ as there are already the options for *started ART before current pregnancy/started ART during current pregnancy*. An additional input line has been added for the dropout rate from ART. For outputs, *HIV+ pregnant women* are no longer an output option because

this created confusion differentiating from *in-need* of PMTCT (the former referred to all pregnancies whereas the latter removes all still births, miscarriages, etc).

Sex differential on treatment

A review of the WHO data for the sex ratio on treatment indicated that women have better access to ART than men, something that was not reflected in Spectrum. Updating the sex ratio of those on treatment in Spectrum to reflect this pattern results in more women on ART but the impact this has on overall mortality is fairly minor.

Fertility adjustment

A question that arose previously was whether a country-specific fertility adjustment (TFR), or a default regional pattern, should be used in Spectrum. A comparison of the results when using the different potential approaches illustrates the substantial difference this can have in some countries and the resultant implications on estimates of need for PMTCT. However, it was discussed that there is a considerable amount of variability in the country-specific data, and as a result, the routine use of country-specific data cannot be recommended. If countries are having an issue with the numbers on PMTCT it would be very useful to review the TFR and consider the use of a country-specific fertility pattern (from survey data, has to be calculated). Many countries have had problems with numbers on PMTCT thus this is something that needs to be closely monitored in the next round of estimates.

Recommendations:

- ✓ **Maintain the regional patterns but recommend that countries to investigate in more detail the potential use of a country-specific pattern instead.**

Follow-up: Futures Institute to include this in the Spectrum manual and UNAIDS to address this in the country workshops, Jan 2013

- ✓ **Review the findings from the ALPHA Network fertility meeting (Feb 2013) and potentially review or reconsider the above recommendation**

Follow-up: Basia Zaba, UNAIDS, Futures Institute, Reference Group, March 2013

Age distribution of incidence

Historically, the AIM model in Spectrum has used Tim Hallett's method for extrapolating incidence from prevalence surveys in ages 15-49 and then further extrapolated to apply this pattern to older age groups. This pattern was then modified for the older age groups following the Ghys/Boerma analysis of available DHS data which found approximately double the number of people at older ages living with HIV compared to Spectrum outputs. The result of this modification was a secondary peak in older age groups which has been somewhat controversial, but has also seemingly improved estimates of people living with HIV in older age groups.

In order to further explore the age distribution of incidence at older ages, Tim Hallett's model was re-conducted using updated survey data and splitting the 5-year age groups into single ages. This method was applied to 20 countries to analyse the results. Then, Futures Institute modified Tim Hallett's method to address the concern of aggregated standard age patterns. The Futures Institute method takes advantage of the mortality and migration patterns in Spectrum (setting incidence to zero, projecting between two surveys to determine incidence required to match the second survey). Results from both methods were compared to the previous default patterns used.

From the results, a few patterns suggest a secondary peak in older ages but many do not. Overall, there are different patterns by sex and a high amount of variation. Looking at the new age distribution of incidence pattern compared to the old distribution, for males the secondary peak was artificial. For females, there might have been a previous misinterpretation on the exposure issue -- this was recalculated and moves the initial peak to 20-24. Overall the changes do not make huge differences. Removing the secondary peak will result in a smaller number of older people who are HIV+; however, demographers will be pleased with this modification as they were not in agreement with the second peak. The overall verdict may be that the CIs are very high in the older age groups.

Recommendations:

- ✓ **Decision: Use a revised age distribution of incidence without the secondary peak in incidence.**
- ✓ **Wait to do the specific comparisons to the survey data once all the final changes have been completed in Spectrum.**

Follow-up: Futures Institute, Jan/Feb 2013

Sex ratios of incidence

Incorporating the recent survey data available, new calculations have been made for the F:M sex ratio of the number of new infections (note, not rates). The previous default value used for SSA was 1.38, after re-analysis incorporating the recent survey data, this ratio reduces to approximately 1.3 and possibly as low as 1.2. For countries in SSA, there is broad clustering near this ratio and thus no good reason to switch to the use of country-specific ratios of F:M incidence as the default. It was also discussed that if the methods were changed to instead use ratios of rates then a reference age would probably be used. However, Basia Zaba has illustrated that this ratio is changing across sex and age over time as ART has become widely available. With more women on ART than men, men have become more protected.

Recommendations:

- ✓ **Maintain the use of a regional default for the sex ratio of incidence.**
- ✓ **Include in the Spectrum manual for countries to be aware of this default value and provide guidance for use of a country-specific ratio calculated from national survey data.**

Follow-up: Futures Institute, Feb 2013

Paediatric mortality on ART

Data from the IeDEA Consortium are used for the patterns of adult survival on ART. IeDEA Consortium also has data from children and it was anticipated that these data would be used to update the current default patterns for paediatric mortality on ART (which are informed by an expert review from a single study). However, the data from IeDEA have extremely low mortality, ½ the mortality compared to adults which does not seem plausible. CY is supposed to have an update imminently.

Recommendations:

- ✓ **Await updated data and analyses from Constantin Yiannoutsos (IeDEA).**
- ✓ **Review the literature available to identify if there are other new sources of data that may inform.**

3. Data from ALPHA Network

Age-specific pattern of incidence from ALPHA Network sites

Using data from the ALPHA Network, Basia Zaba calculated smoothed hazards for incidence by age and time period of ART availability (pre-ART, during ART rollout, ART widely available), by site and from a pooled dataset for three East African sites. Note that it was not possible to interpret pooled data from all sites due to rapid changes over time and sites contributing data in different years. The analyses were done using 5-year age groups (which resulted in inconsistent trends, large confidence intervals) and 15-year age groups. Because the changes over time and the relationships (by sex and between sites) are not proportional, a Cox hazard analysis is not appropriate. The shape of the hazard function is also too skewed to fit most standard distributions, thus a cubic spline model was fitted to the pooled dataset. Overall, the changes in age patterns of incidence over time are unclear; however, incidence is falling faster from men than for women in the post-ART era. It was discussed that the age-specific rates are not directly comparable to Spectrum (which uses an age distribution of incidence).

Recommendations:

- ✓ **Basia Zaba to calculate the distribution to compare to the Spectrum pattern and John Stover to calculate the age-specific rates from Spectrum to compare to the pooled dataset (with the caveat that it is from three sites located in Uganda and Tanzania)**

Follow-up: Basia Zaba and John Stover, Jan 2013

- ✓ **Consider the use of age-specific calculations of rates instead of the distribution in Spectrum in the future; however, further analysis is needed to fully understand the implications of these changes (may further squeeze older age groups).**

Follow-up: Futures Institute, medium-term research agenda, June 2013

Survival to older ages in ALPHA Network data

The sex differences for survival (HIV+) can no longer be ignored. The previous conclusion that there was no sex difference was erroneous. In the pre-ART era, men have a slight survival advantage, likely due to later age at infection. In the ART-rollout era, sex differences begin to disappear, and then in the post-ART era, women have clear survival advantages as a result of more women on treatment and at earlier ages. In summary, ART is having a tremendous impact on sex differences for survival.

Recommendation: These findings further support the September 2012 recommendation to include a sex ratio on treatment.

4. Update on progress on revised CD4 progression parameters

Alternative CD4 models and review of CD4 data, *Peter Johnson and Eddas Bennett*

The current parameters used in Spectrum are difficult to investigate and test because the CD4 boxes are different widths (used to accommodate the mortality parameters). Using the 10 year age groups, the parameters change when you change age groups, which cause artificial jumps. Additionally, Spectrum is causing people infected at age 20 to die too early compared to the ALPHA network. The progression parameters in Spectrum are based on current age; however, age at infection may be a more suitable option to use. As a result, Peter Johnson considered the use of alternative CD4 models – a continuous model and a time since infection model.

The CDC has conducted a literature review on CD4 which may be useful to provide a better understanding for CD4 level at initiation (seroconversion) and to help inform how to distribute those newly infected by CD4. Currently, Spectrum allocates the majority of newly infected into the >500 CD4 bin, a proportion into the 350-500 CD4 bin (~20%) and no one in bins <350 CD4.

Updated results from pooled CD4 dataset

Nikos Pantazis has run the linear models on the different subgroups and on high income and low income (model used in Lodi et al paper, linear fit to square root of CD4, by sex and both age at seroconversion and duration since seroconversion). The two main questions that arose during duplication of the Lodi analysis:

1. Include different progression for high income vs low income?
2. Even after adjusting for age, there is a significant interaction between sex and rate of decline which is inconsistent with survival patterns in Spectrum (based on Todd paper where women survived longer but not significantly after adjusting for age thus the survival patterns were kept the same for males and females in Spectrum).

It was discussed that the data from high income showed shorter progression which would then further increase mortality and therefore is not helpful. It was also discussed that the data are not good enough data to allow for extrapolation to lower CD4 counts.

Recommendations:

- ✓ **The current best evidence is the square root model. Jeff Eaton to send the age-specific CD4 distributions (percentages) by the end of the week and will continue to work on the revised CD4 parameters with John Stover and Peter Johnson (need to decide whether to include a sex differential).**
Follow-up: Jeff Eaton, John Stover, Peter Johnson, review Jan 2013
- ✓ **Use the reconfigured set of best estimates from Peter Johnson's model to test for South Africa (mortality) and also for comparison with the Uganda AIS data.**
Follow-up: John Stover, Peter Johnson, review Jan 2013
- ✓ **Wait to try to define regional patterns -- there are still more potential data to be included in the analysis.**

5. Model testing

The Spectrum model will need to be fully tested in advance of the Training of Trainers and the country workshops.

Recommendations:

- ✓ **Model testing to occur between 10 Jan and 15 Feb and to involve multiple groups to conduct the testing.**
- ✓ **Unfuddle can also be used to coordinate the feedback from testing.**

Follow-up: UNAIDS to generate testing checklist of items (with Futures Institute and EPP team), and will generate a proposal and invite model testers, Jan 2013

Follow-up: Futures Institute will do comparisons with the previous version of Spectrum; EPP team will run full standard series of testing, Jan 2013

Appendix I: Meeting Agenda

Technical Meeting, Spectrum 2013 Geneva, 5 December 2012

Venue: UNAIDS headquarters, room D46031

Time: 9:30am – 6 pm, Geneva time (CET)

Chair: Tim Hallett

(9:45-10:30)

EPP Part I

Status update and review of new features, Tim Brown

(10:45-12:15)

Spectrum

Review and discussion of new assumptions in Spectrum

1. Sex ratios

- a. Review results after implementation of numbers on treatment by sex, including changes to mortality, prevalence ratios and incidence ratios, *John Stover*
 - Review differential treatment access in children too? (UNAIDS?)
- b. Review/discuss testing different default patterns for sex ratios of incidence (*testing country-specific values from surveys, use of 1.5 in generalised epidemics if CIs overlap 1.5, the potential use of regional defaults*), *John Stover*

2. Incidence by age patterns

- a. Observed age-specific incidence patterns from ALPHA sites and Survival at older ages, *Basia Zaba*
- b. Implementation of updated incidence pattern and review of results, *Carel Pretorius/John Stover*

3. Changes made to TFR

4. leDEA data

Review of results from updated assumptions for:

- Paediatric ART patterns
- North America/Europe pattern
- Extrapolation for survival on ART >350 CD4

(1:30-3:45)

EPP Part II -- Model Evaluation

Curve fitting approaches for EPP

- b. Review and discussion of results using established criteria and important differences
- c. Discussion of approaches, decision for moving forward
 - i. Recommendations for approaches to use for different situations -- generalised and concentrated epidemics
 - ii. Recommendations for models to include in EPP

- iii. Recommendations for communication (of change in approach, changes in estimates, what differences might be expected)

EPP Part III

Empirical results from inflating uncertainty as a result of “missingness” and, Inclusion of DHS data in the likelihood, Dan Hogan (30 min)

(4:00-5:30)

CD4 progression

Update of progress surrounding CD4 progression in Spectrum

1. **Alternative CD4 models and review of CD4 data (20/25), Peter Johnson/Eddas Bennett**
2. **Updated results from pooled CD4 dataset (20/25), Jeff Eaton**

Appendix II: List of Participants

Le Bao

Penn State
State College, Pennsylvania, USA

Eddas Bennett

CDC
Atlanta, Georgia, USA

Tim Brown

East-West Center,
Honolulu, Hawaii, USA

Txema Calleja

WHO
Geneva, Switzerland

Kelsey Case

Department of Infectious Disease Epidemiology
Imperial College London, UK

Jeff Eaton

Department of Infectious Disease Epidemiology
Imperial College London, UK

Peter Ghys

UNAIDS
Geneva, Switzerland

Tim Hallett

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Imperial College London, UK

Dan Hogan

Harvard School of Public Health
Boston, Massachusetts, USA

Peter Johnson

US Census Bureau
Washington DC, USA

Mary Mahy

UNAIDS
Geneva, Switzerland

Carel Pretorius

Futures Institute
Glastonbury, CT, USA

Karen Stanecki

UNAIDS
Geneva, Switzerland

John Stover

Futures Institute
Glastonbury, CT, USA

Basia Zaba

LSHTM
London, UK

Appendix III: Model Evaluation Criteria

Teleconference decision points 8 November 2012

Metric: Mean absolute error in absolute space for evaluation

- ✓ MAE in probit space will also be calculated, to be reviewed separately but will not be part of the explicit evaluation criteria.
- ✓ Metric will be rounded to three significant digits; a tie will result in the full points awarded to each model
- ✓ The models must outperform EPP classic to be awarded points
- ✓ Dan Hogan to send Tim Brown the exact formulas to calculate the MAEs
- ✓ Le Bao to further explore the behaviour of the different metrics

UNAIDS guidance:

Test 1. Full dataset

Test 2. Make separate dataset, delete every data point from 2007 to present

Test 3. Make separate dataset, delete everything before 1995

Test 4-5. Need figures to review

Tiebreak. Plot $r(t)$ plots to evaluate in the event of a tie

For generalised epidemics, urban datasets will be used unless the rural dataset has already been specified for evaluation (excel spreadsheet).

For concentrated epidemics, UNAIDS will select specific subpopulations to test from the countries specified. The formal evaluation criteria will not be used for concentrated epidemics.

Evaluation criteria for generalised epidemics, metric, hierarchy weight (points)

1. **In-sample fit:** Goodness of fit, fit all data points, assess fit to points from 2007-12 (3pts)
Metric: MAE in absolute space (rounded to 3 significant figures)
2. **Out-of-sample fit:** Goodness of fit, fit all data points through 2006, assess fit to points from 2007-12 (2pts)
Metric: MAE in absolute space (rounded to 3 significant figures)
3. **Out-of-sample fit:** Goodness of fit, out-of-sample prediction of data points pre-1995 (1pt)
Metric: MAE in absolute space (rounded to 3 significant figures)
4. **Qualitative indicator:** Credible forward projection for incidence, 2012-15 (0.5pts)
5. **Qualitative indicator:** Credible performance in a data-free zone (0.5pts)

Rules for testing:

- No priors on prevalence (at least start this way), no DHS data
- Blind the models
- Share points if MAE is the same when rounded at 3 decimal points

Models:

- Spline with random walk
- 7 parameter r trend

Operationalization

- Run these models for the countries listed, review results as a matrix to identify performance across defined instances
- Qualitative indicators: Documentation for why one model fit is selected over the other

Tie break criteria (if unable to determine based on above criteria)

- $r(t)$ curve screening
- time taken to run the model

Country list for testing metrics in generalised epidemics:

Countries with an historic rapid ART scale-up: **Botswana**

Countries with strongly declining epidemics: **Zimbabwe and Ethiopia**

Countries with strongly rising epidemics: **Gabon Rural and Sierra Leone Rural**

Countries with very sparse datasets: **South Sudan, Angola rural**

Countries with very large datasets: **Tanzania, Nigeria, Ghana**

Countries with big 'data free zones' at the beginning of the epidemic: **Benin rural, Liberia**

Countries with a "wobble": **Uganda, Kenya**

Concentrated epidemics: Argentina, Peru, Honduras, Guatemala, Bolivia, Armenia, Ukraine, Kazakhstan, Moldova, Lao

Recommendations needed

Generalised epidemics

Model rec for countries with dense data: r trend or spline

Model rec for countries with sparse data: r trend, spline, EPP classic

Concentration epidemics

Model rec for subpopulations with dense data: r trend or spline

Model rec for subpopulations with sparse data: r trend, spline, EPP classic

Model rec for subpopulations with 1-2 data points: r trend, spline, EPP classic