Integrated Health Tool for planning and costing (IHT)

Tuberculosis module

Dynamical impact model

Department for HIV, Tuberculosis, Hepatitis and Sexually Transmitted Infections

Last updated: **September 2025**

World Health Organization

Integrated Health Tool for planning and costing

END TB

Outline

1. Overview of dynamical impact model used in the TB module of IHT
2. Model calibration
   - Completed for 29 high burden countries in TGF TB portfolio
3. User interface
4. Role of dynamical model in the Target Population component
   - Hazard ratios and mapping them to parameters of the dynamical model
   - Impact from the dynamical model
   - Example of modeling NSP objectives
6. Practical considerations on use of dynamical model in TB national strategic planning
7. Practice steps using the demonstration video on the WHO website using an example projection/scenario

World Health Organization

1: General description of the dynamical model

World Health Organization

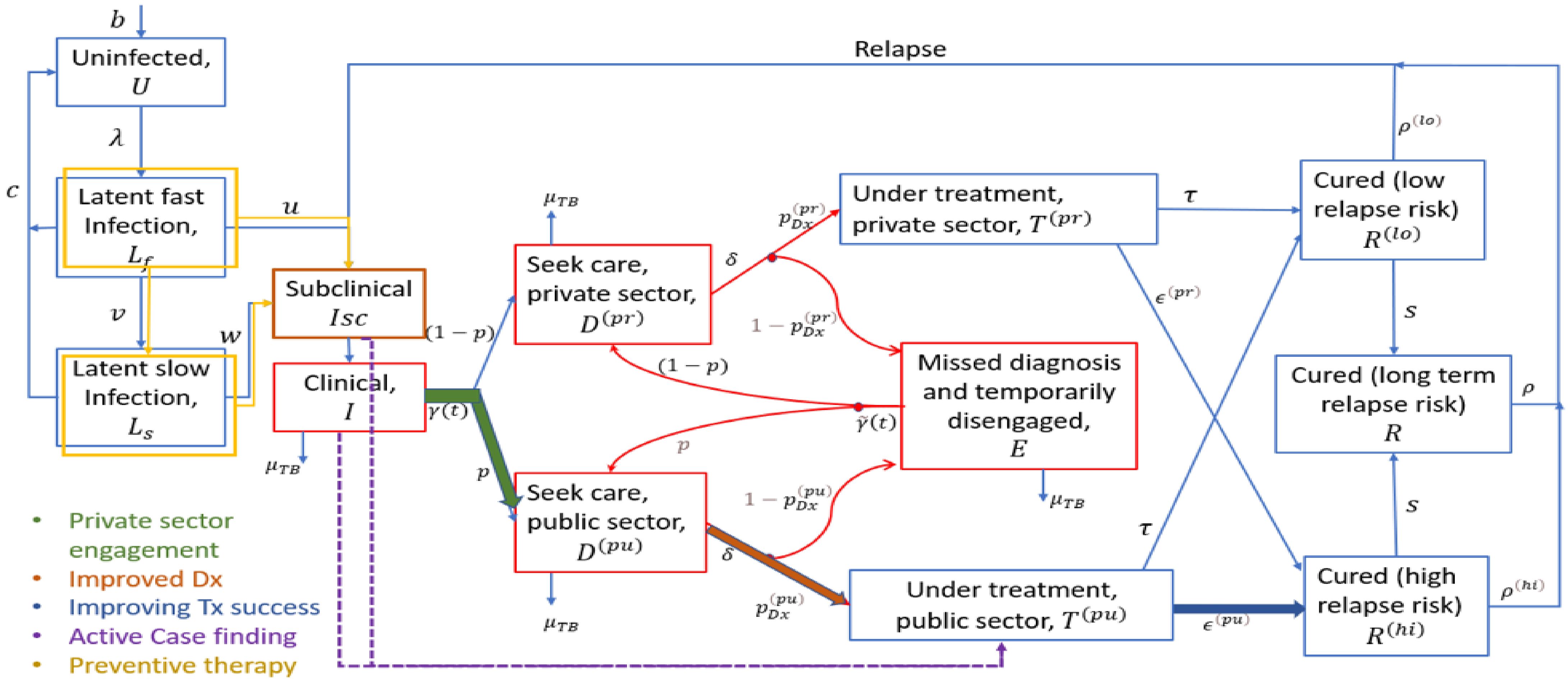
1: General description of the dynamical model

The dynamical model is based on processes natural history of TB, including:

- Community-level transmission of one drug sensitive and one drug resistance strain (taken to be RR).
- Leading to the processes of TB infection and active TB disease, re-activation and re-infection of patients with latent infections, TB related mortality, self-recovery and recovery following the completion of a treatment cascade.
- The treatment cascade can be described as:
- Screening, diagnosis, DST, linkage to first line and second line treatment, treatment completion or default, and preventive treatment where applicable. Patients experience various delays and movements in the cascade.
- The model has explicit structure for service provision through public/NTP and private sector/non-NTP service providers.
- The overall, non-NTP and the MDR specific model structure is depicted below:

1: Diagram of the dynamical impact model in IHT

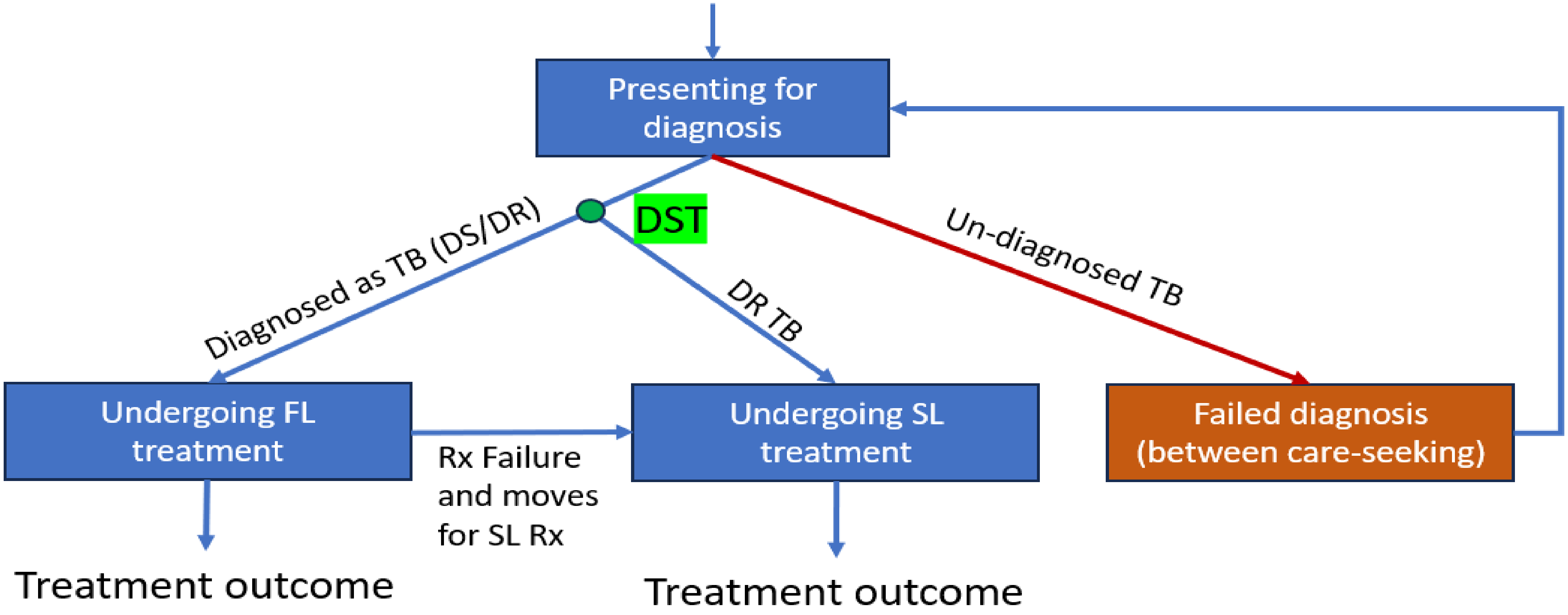
The model is based on a model developed as part of global collaboration with TGF, STB and TBMAC.



World Health Organization

1: MDR intervention structure

Upfront-DST allows early DR-TB detection



2: Calibration data

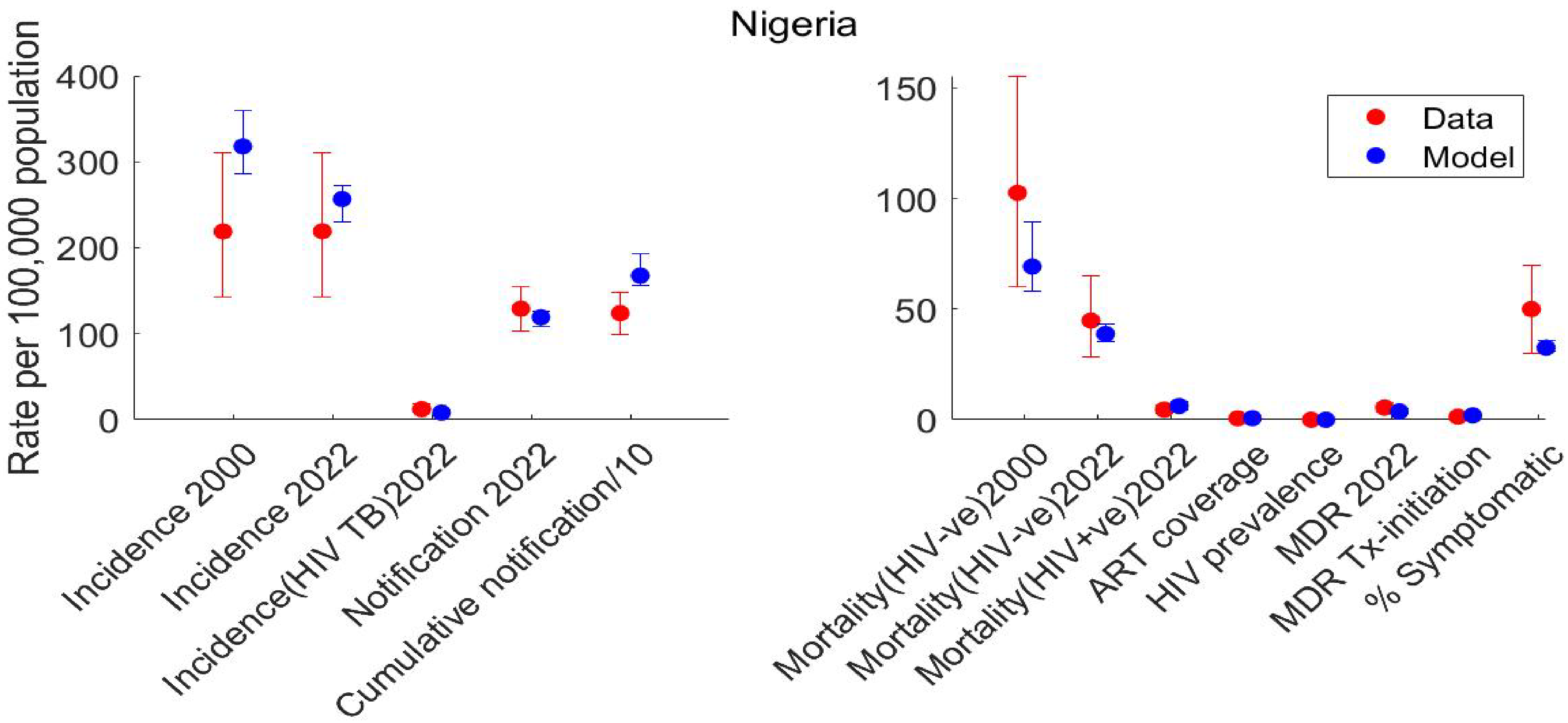
2: Calibration data

- Total TB incidence 2000 and 2022 (WHO)
  - 2000 and 2022 data established a general historical trend
  - The models are calibrated to public data for 2022 and an update to 2023 of models depends on funding availability
- HIV-positive TB incidence 2022
- Notification in 2022 (WHO) and cumulative notification over the period of 2000-2022 (/10 to fit on the same chart)
- HIV-neg TB mortality 2000 and 2022 (WHO) [Except DPR Korea]
- HIV-pos TB mortality 2022 (WHO) [Except for DPR Korea]
- HIV prevalence 2022 (Spectrum AIM)
- ART coverage 2022 (Spectrum AIM)
- MDR incidence in 2022 (WHO)
- MDR treatment initiation rate in 2022 (WHO)
- Proportion of prevalent patients that are symptomatic (assumption based on other country survey)

World Health Organization

2: Calibration result

A statistical mode-fitting method is used to calibrate the model against available data, providing confidence intervals for the model's projections too. The calibrated model is available in the TB module of IHT.



3: User interface related to impact modeling using the dynamical model

- The *Target population estimation* component is used in its current form and is not specifically changed to interact with the dynamical model. That is, detection and care cascades are defined for 20 population in patient (10 population) and provider-initiated (10 population) programs.
  - This TB-program-information defines impact inputs for the dynamical model, just like it does for the Statistical model.
- The dynamical model's structure is shown to the user in the form of structured listing of its model parameters.
  - This is done for reasons of transparency and not for encouraging user calibration of the models
- The Impact editor states the hazard ratios that define impact:
  - Total number notified (#)
  - Reduction in population-level risk for TB disease (adjusted for higher risk in population groups receiving TPT) (%)
  - Treatment success rate (%)

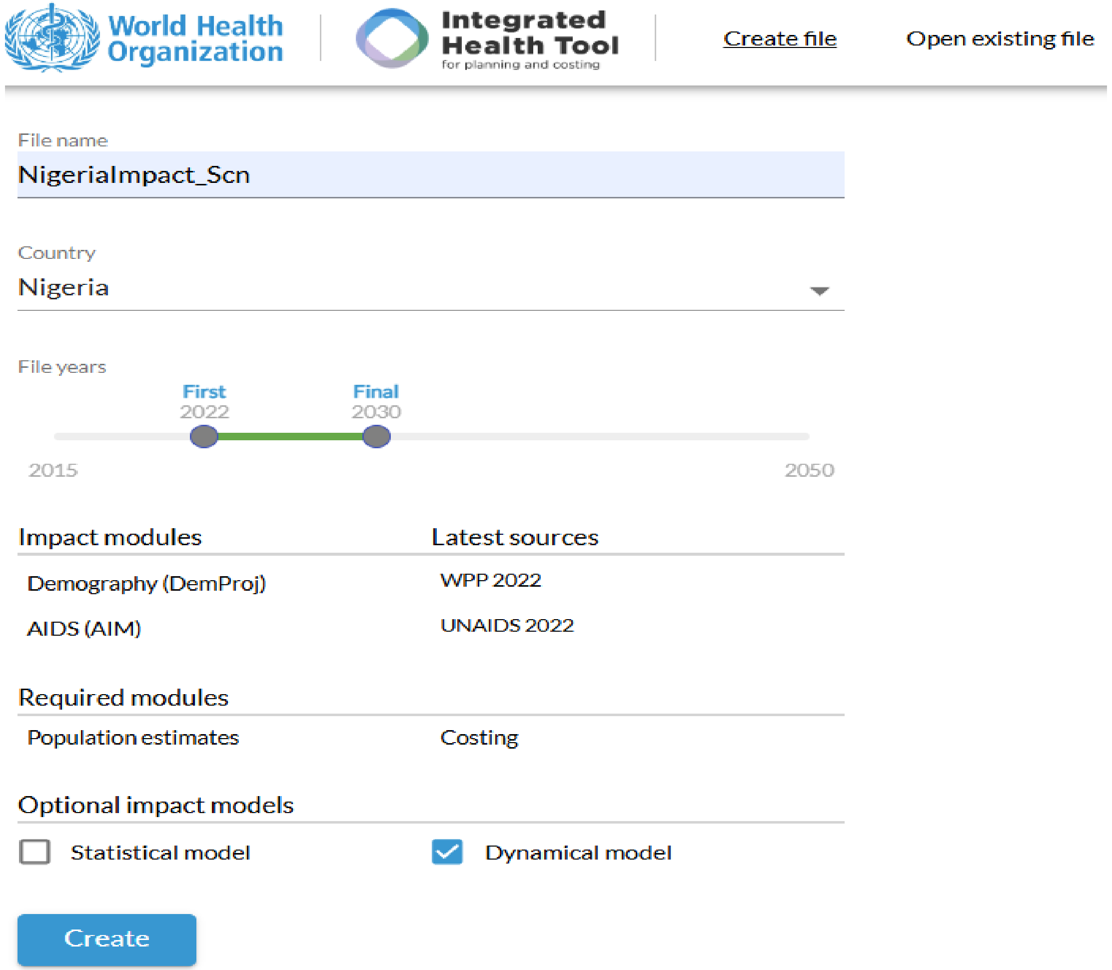
World Health Organization

3. Creating a projection that uses the dynamical model

Calibrated models are only available for 29 high burden countries:

AFG,AGO,BGD,CMR,COD,ETH,GHA,IDN,IND,KEN,KHM,MDG,MMR,MOZ,NGA,NPL,PAK,PER,PHL,PNG,THA,TZA,UGA,UKR,UZB,ZAF,ZWE,ZMB,VNM

Among the top 30 HB and GF-eligible countries DPRK has insufficient data for calibration



World Health Organization

3: From calibration to user interface

- The parameter values of the 29 calibrated models are available for use in IHT. (Calibration parameters differ from their default values as they are changed in the fitting process)
- These parameters are sent to IHT TB via a database, and they are then presented to the user in a structured user interface.
- The process of calibrating the model to a country is complex and time-consuming and it took the Avenir Health team a couple of months to calibrate the 29 models. Minimum requirements to perform a calibration include:
  - Familiarity with dynamical TB models,
  - Analysis of calibration data,
  - MCMC methodology, convergence criteria, and so on.

3: User interface of the impact mechanism

3. User interface to the parameters of the dynamical model

The user interface provides a transparent listing of the model parameters. The user is not recommended to change these parameter as the model would then no longer fit the calibration data.

World Health Organization | Integrated Health Tool for planning and costing | NigeriaImpact_S... Nigeria 2022-2030

1 Configuration — 2 Demographics and HIV — 3 TB Target population estimation

Impact (dynamical model)

Calculate

TB natural history parameters | TB care cascade | Demography-related | Vaccine-related

Description	Value	Include?
TB natural history parameters		
Transmission		
Infection rate (number of annual infections per case) of DS TB	6.799	☑
Social contact matrix (multipier on infection rate, differentiated by age of TB contact and age of TB index)		☐
TB contact: aged 0-4 years, TB index: aged 0-4 years	1.093	
TB contact: aged 0-4 years, TB index: aged 5-9 years	0.485	
TB contact: aged 0-4 years, TB index: aged 10-14 years	0.164	
TB contact: aged 0-4 years, TB index: aged 15-64 years	0.617	
TB contact: aged 0-4 years, TB index: aged 65+ years	0.015	
TB contact: aged 5-9 years, TB index: aged 0-4 years	0.561	
TB contact: aged 5-9 years, TB index: aged 5-9 years	3.130	
TB contact: aged 5-9 years, TB index: aged 10-14 years	0.748	
TB contact: aged 5-9 years, TB index: aged 15-64 years	0.790	

World Health Organization

3. Triggering a model calculation

- **Hitting the Calculate button in the dynamical model editor does not trigger a calibration of the model**. As mentioned, calibration is a complex and time-consuming process, and it not currently planned to do calibration directly from the tool's interface.
- **It triggers a forward projection**, between the first and final years of the projection. Note that the history of the model prior to 2022, as implied by its set of parameters, is not recalculated as part of a forward projection. The 2022 state is saved and retrieved for to enable the forward projection starting at 2022.
- In this forward projection the Impact ratios are used to adjust intervention parameters in the model.
- These ratios have the value 1 for a baseline projection, meaning the baseline and scale-up section of the Impact editor have the same rates coming from a calibrated and configured baseline model.
- **As is the case with the statistical model, the user manages Baseline and Scale-up files to study the impact of an intervention or a package of interventions**.

World Health Organization

4: Estimating impact via the Target population estimation component

World Health Organization

4. Estimating impact via the Target population estimation component

- Three impact elements ('hazard' rates) are used, as in the statistical model:
  - Increased probability of detection via increased notification (Hd)
  - Decreased risk of TB disease (Hi)
  - Decreased risk of mortality for those receiving treatment (Ht)
- The ratios of these 'hazards' between a baseline and scale-up scenarios are sent to parameters of the model that define TB epidemiology and TB interventions.
- The choice of these three impact summary variables/rates are based on:
  - Using a common method between the statistical and dynamical models
  - Partial Rank Correlation Coefficient analyses using the dynamical model showed that these parameters are the most influential on impact on TB burden.

4. Estimating impact via the Target Population component

- HRd maps to :
  - Model parameters that the determine the probability of being screened and detection including early detection
  - Parameters that determine the probability of being diagnosed (sensitivity)
  - Upfront DST can also be quantified from the TP component for use in the Dynamical model.
- Example: HRd =(20,000-10,000)/(10,000) = ->100% increase notification and probabilities of being detected

World Health Organization

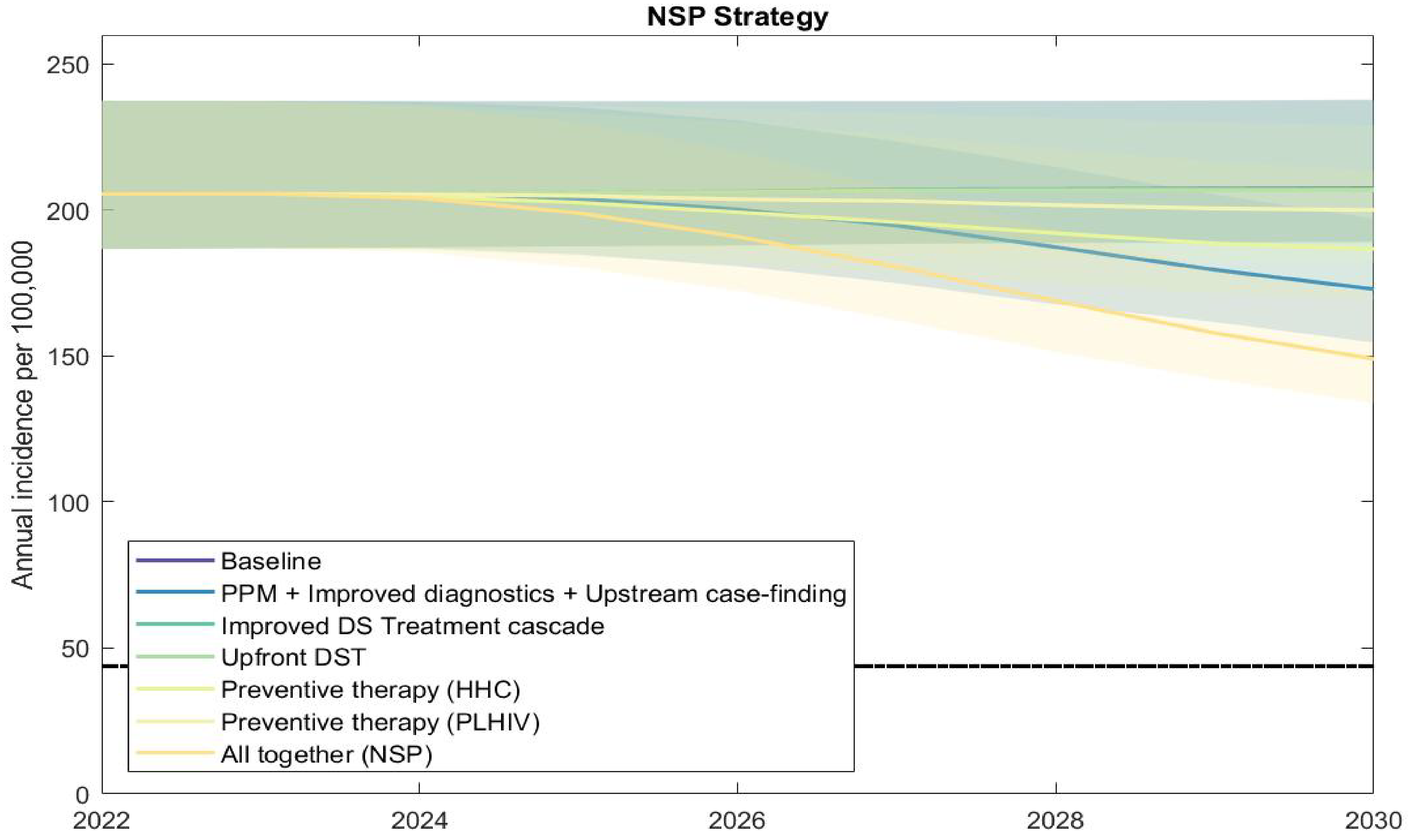
4. Estimating impact via the Target population estimation component

- HRi maps to:
  - Regression and progression parameters in the model
- HRt maps to:
  - Treatment success for FL and SL patients.
  - Default rates, to the extent they are determined by DST availability, can be quantified from the TP component and can be adjusted in the Dynamical model.
  - The average duration of SL treatment can be reduced in the model if a shift to short-course regimens is represented in the TP component.

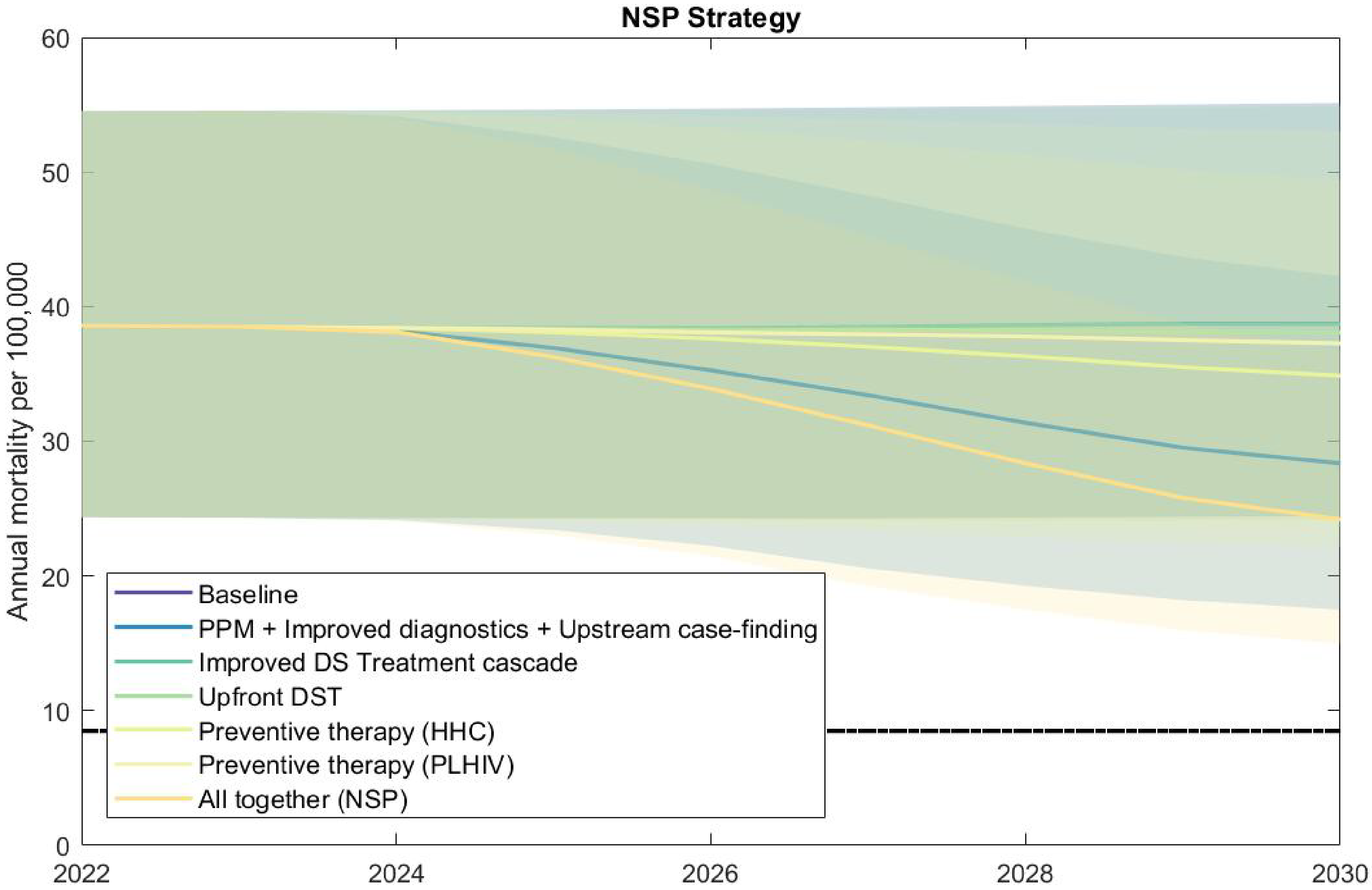
4. Linear interpolation between a first and last year of scaleup

- The model parameter updates that are implied by the hazard ratios HRd, HRi and HRt is achieved via linear scale-up between the first year and the final year of intervention scale-up.
- Intervention coverage is kept constant after the final year of scale-up
- The user can adjust this scale-up interval to fall between the first and final year of the project.
- This is different to the statistical impact model where the HRs are calculated for all years of the projection, directly from the Target Population component.

4. Impact of NSP objectives on TB incidence

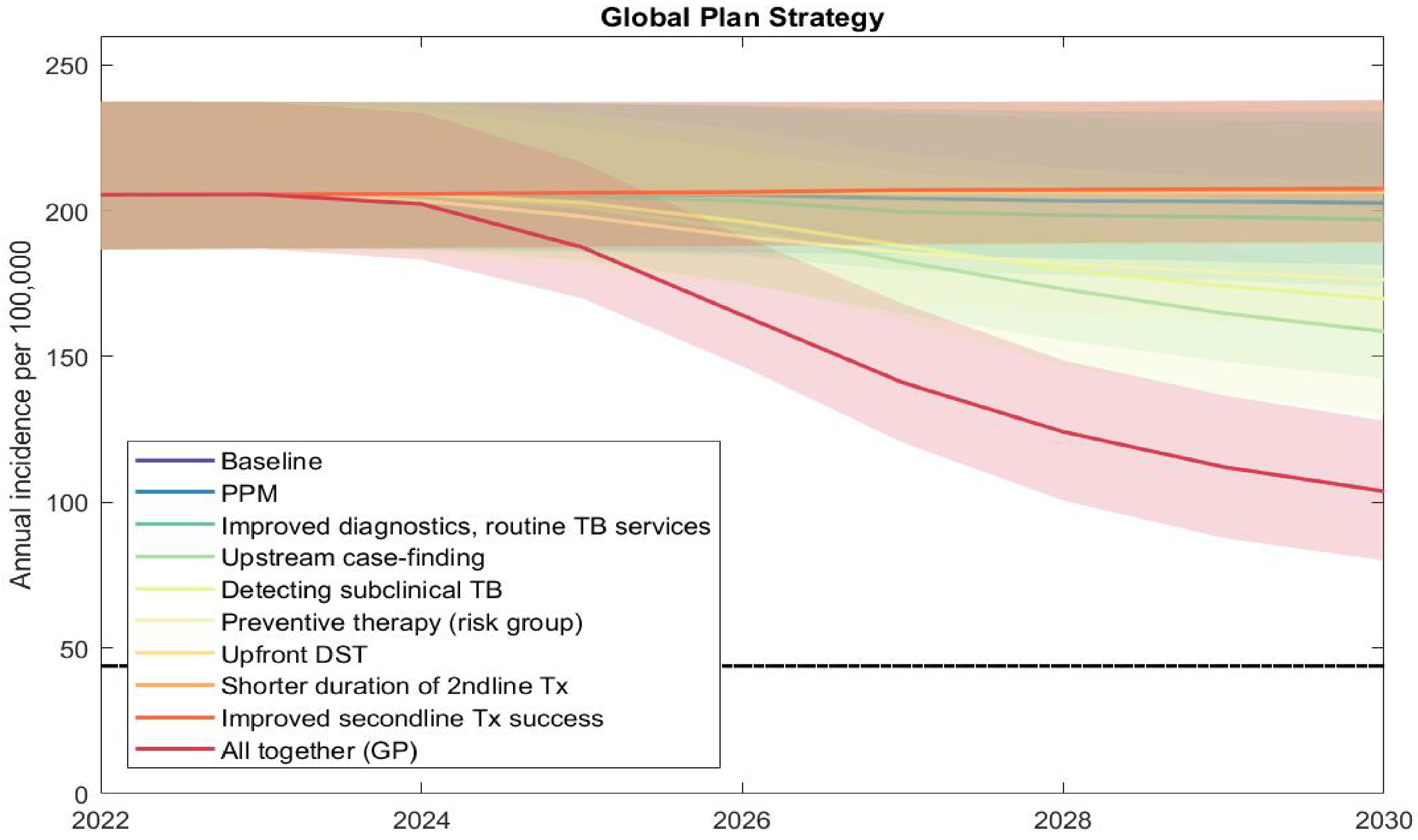


4. Impact of NSP objectives on TB deaths

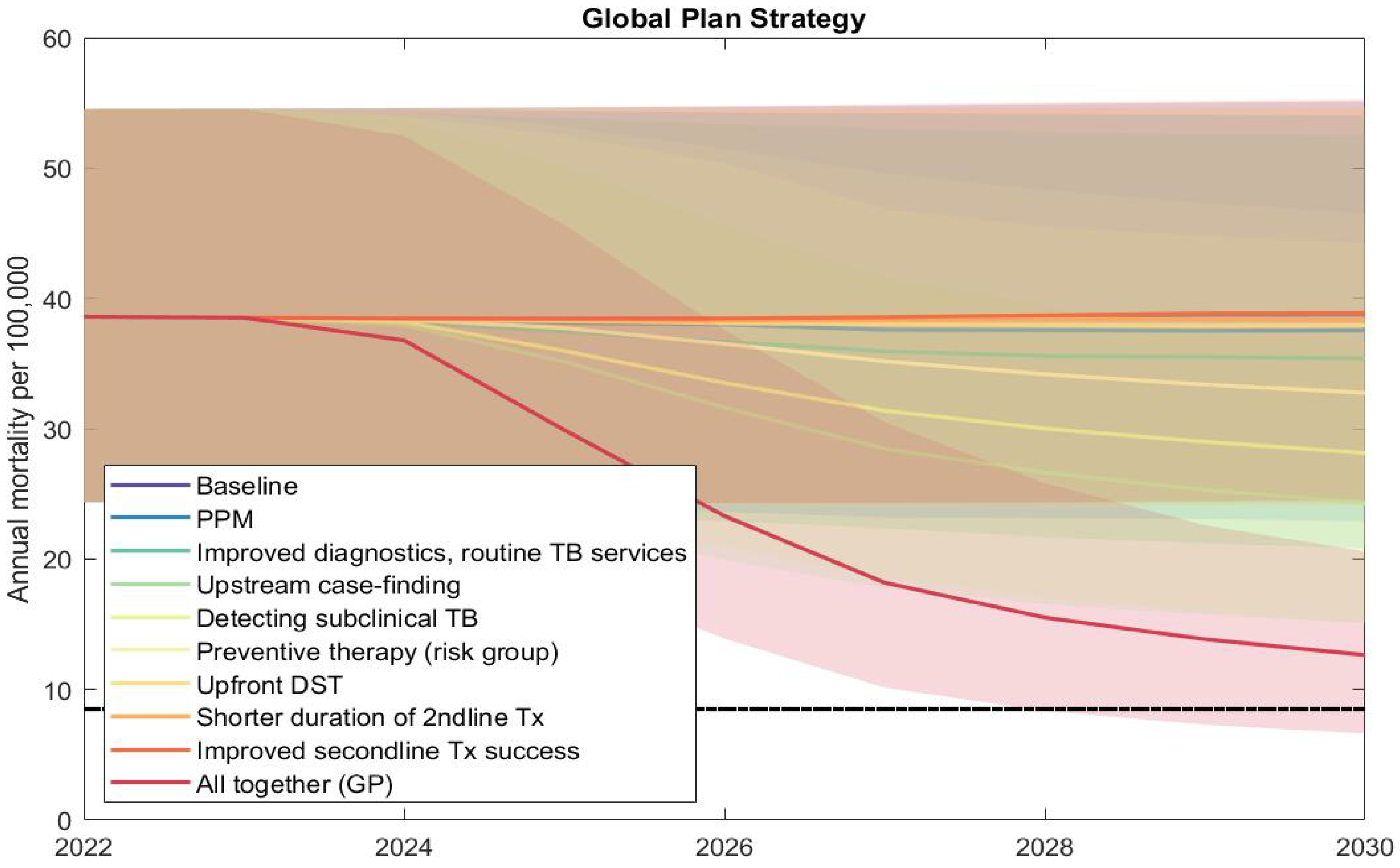


World Health Organization

4. Impact of TB Global Plan 2023-2030 objectives on TB incidence



4. Impact of TB Global Plan 2023-2030 objectives on TB deaths



5: Practical considerations on potential use of dynamical model in TB national strategic planning

World Health Organization

5. Practical considerations

- The dynamical model has been calibrated for 29 high burden countries using 2022 data.
- The process of calibration is complex and time-consuming making it unlikely for a non-expert (someone not experienced with dynamical TB models) to calibrate the model successfully, for several reasons:
  - Python’s ODE solver is relatively slow for each model run
  - MCMC requires thousands of model runs
  - Several iterations of the algorithm may be needed to reach convergence, and the user may need to guide convergence.
- Using the existing Target population estimation component allows for direct use of the TP interfaces to produce impact estimates using the dynamical model, while using a simple intervention framework consisting of 3 impact ratios: HRd, HRi and HRt that are prepared in the Target population estimation component and then sent to dynamical model for impact estimation.
- The use of the same impact ratios as is used by the statistical model allows for a comparison between impact results between the statistical and dynamical models although a detailed comparison have not yet been conducted.

World Health Organization

5. Practical considreations

- The statistical model works well, without the burden of model calibration, to produce reliable short-term impact estimates. The statistical model can however be pushed beyond its domain of reliable use. For example, pushing notifications too high, for too long, leading to conditions where underlying assumptions of the statistical model no longer hold.

- The dynamical model carries a significant calibration burden to the extent that it is unlikely that someone unfamiliar with the model and its inner workings can produce reliable calibrations. However, it handles time-dynamics better than the statistical model and, for example, will handle high notification targets better. It is expected to handle 'new' interventions better (such as large scale-vaccination or earlier detection or detection of non-symptomatic TB) than the statistical model, which relies on past evidence for secondary impact on incidence.

- There are many important aspects of target setting generally not considered by a general user that will lead to both models producing unreliable results. These include unrealistic notification targets being set, a lack of impact anticipation in notification target setting (leading to notification far exceeding projected incidence), and a lack of understanding/guidance regarding the role of early detection and the average disease duration, which is a critical aspect of impact in dynamical models

World Health Organization

6: Practice steps using the dynamical model demonstration video* on the WHO website

1. Follow the process of creating a projection using a dynamical model
2. Follow the demonstration of making a copy of the baseline file to create a scale-up scenario
3. Follow the preparation of the impact ratio section of the baseline projection to the scale-up projection
4. Create impact in the scale-up file by increasing:
   - Total notification
   - TB prevention in provider-initiated populations
   - Treatment success in the Impact editor, noting that this input is not explicitly captured in the care cascade, but is assumed to be implicitly captured by increasing DST and appropriate and timely regimen allocation

*Watch demonstration video on WHO website: