Guidance for country-level TB modelling

World Health Organization

TB Modelling and Analysis Consortium

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Contents

Acknowledgements v
Abbreviations vi
Executive summary 1
Chapter 1: Introduction 4
1.1 Policy context 4
1.2 Rationale for modelling 5
1.3 Demand for modelling 5
1.4 Current challenges 6
1.5 Existing guidance 7
1.6 This guidance 7
Box 1.1 When to use a model 8
Chapter 2: Development process, scope and target audience 9
2.1 Process and stakeholders 9
2.2 Scope 9
2.3 Target audience 10
Chapter 3: Principles and good practices for country-level TB modelling 11
3.1 Principle 1 – Relevance 15
3.2 Principle 2 – Realism 16
3.3 Principle 3 – Appropriateness of model structure 18
3.4 Principle 4 – Consideration of all evidence 20
3.5 Principle 5 – Validation 22
3.6 Principle 6 – Informativeness 23
3.7 Principle 7 – Transparency 25
3.8 Principle 8 – Timeliness 27
3.9 Principle 9 – Country ownership 28
3.10 Principle 10 – Iteration 30
Chapter 4: The modelling process 31
Bibliography 34

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Abbreviations

DALY	disability-adjusted life years
Global Fund	Global Fund to Fight AIDS, Tuberculosis and Malaria
iDSI	International Decision Support Initiative
LTBI	latent TB infection
NTP	national TB programme
PSA	probabilistic sensitivity analysis
QALY	quality-adjusted life years
SDG	Sustainable Development Goal
TB	tuberculosis
TB MAC	TB Modelling and Analysis Consortium
USAID	United States Agency for International Development
WHO	World Health Organization

Executive summary

The use of mathematical modelling to inform and support tuberculosis (TB) policy-making has been encouraged by major funders and adopted by several high-burden countries. These quantitative planning exercises are undertaken to provide evidence for proposed interventions, improve the impact of TB funding and support funding applications. In recent years, a number of technical assistance providers have developed mathematical models and technical assistance capacity to support in-country TB policy decisions, and it is expected that the demand for technical assistance to support TB modelling will increase.

The WHO Global Task Force on TB Impact Measurement provides global oversight to ensure that assessments of progress towards ending TB at global, regional and country levels are as rigorous, robust and consensus based as possible. The Task Force supports countries to improve the analysis and use of TB data for policy, planning and programmatic action, and is committed to the ongoing improvement of model-based policy analysis as a tool for strategic planning and budgeting.

This document aims to provide concrete, pragmatic guidance for how TB modelling and related technical assistance is undertaken to support country decision-making. The target audience for this document are the participants and stakeholders in country-level TB modelling efforts, including the individuals who build and apply models; policy-makers, technical experts and other members of the TB community; international funding and technical partners; and individuals and organizations engaged in supporting TB policy-making.

The document describes 10 principles for country-level TB modelling:

1. **Relevance:** Modelling should assess the policies and outcomes relevant to the country context and decision being made.
2. **Realism:** Modelling should explicitly consider implementation challenges that may reduce the effectiveness or increase the costs of interventions when introduced into routine practice, and should examine the plausibility of assumptions required for policy success.

3. **Appropriateness of model structure:** The model design should be justified in terms of the policy questions and local context being considered – the structure should be sufficiently detailed to represent the mechanisms generating policy outcomes but avoid unnecessary complexity.

4. **Consideration of all evidence:** Modelling should consider all available evidence relevant to the decision problem.

5. **Validation:** Where possible, model results should be compared with evidence not used for model parameterization or calibration, to understand the consistency of modelling results with other evidence.

6. **Informativeness:** Modelled analyses should report a rich set of results describing policy consequences for a range of outputs and outcomes, to provide a deeper understanding of the scenarios being modelled and model functioning.

7. **Transparency:** Modelling results should be accompanied by a clear description of evidence that supports the main findings, the limitations of the modelling approach, uncertainty in modelled estimates and the sensitivity of results to different assumptions. Conflicts of interest should be avoided if possible, but where they are unavoidable they should be described explicitly.

8. **Timeliness:** Modelling activities should be organized to provide results at the time they are required for decision-making.

9. **Country ownership:** Modelling should be conducted with the full participation of local stakeholders at each stage of the process.

10. **Iteration:** Modelling should involve an iterative process of engagement, and should be reconsidered in light of new evidence.

These principles cover the design and estimation of the mathematical models themselves, as well as the approaches used to identify and synthesize evidence, and incorporate modelling into the process of policy identification and comparison. The principles are intended to apply to the estimation of both epidemiological and economic outcomes, and be relevant to any country-level TB modelling exercise undertaken to inform policy-making. Each principle is accompanied by several "good practices" for operationalizing these principles. The document also provides case studies that give concrete examples of how these principles have been applied in typical modelling applications, and a description of how these principles map onto the sequence of activities involved in a typical modelling application. As a separate, parallel work-package to this guidance, the TB Modelling and Analysis Consortium has developed a catalogue[1] of organizations currently engaged in

[1] See http://tb-mac.org/tb-mac-resource/model-catalogue/

providing country technical assistance for TB modelling; the catalogue provides detailed information on the capabilities, approaches and past history of both the models and the modelling teams.

For modellers, this guidance suggests approaches that can improve the quality, relevance and timeliness of modelling work undertaken to support country-level planning. For non-modellers, it describes issues to consider when engaging modelling technical assistance to support a planning process, contributing to a modelling exercise, or reviewing the results of modelled analyses. The principles and practices identified in this guidance document do not represent sufficient conditions for achieving valid modelling results, and should be applied in conjunction with existing guidance focused on other relevant aspects of policy evaluation, such as those for economic evaluation. However, it is hoped that the routine application of these principles will improve the reliability, transparency and usefulness of modelling results for TB policy-making.

Most of the principles and practices described in this guidance serve three higher-level goals: that model-based policy evaluation makes the best use of available evidence; that modelling is incorporated into policy-making in a way that clearly recognizes the strengths and weaknesses of the modelled estimates; and that the modelling supports (rather than replaces) policy-making as a deliberative, country-led process. While this guidance will not respond to all questions that arise in the context of a modelling exercise, it is intended to provide guidance on some of the major questions common to most country-level TB modelling applications.

CHAPTER 1

Introduction

1.1 Policy context

In the era of the Sustainable Development Goals (SDGs) and the End TB Strategy, the global tuberculosis (TB) community has set ambitious targets for reductions in TB incidence and mortality, including the reduction of global TB incidence by 80% by 2030 and by 90% by 2035, and of global TB mortality by 90% by 2030 and by 95 by 2035, compared with their 2015 levels *(1, 2)*. To achieve these targets, national TB programmes (NTPs) need to identify ways to accelerate their efforts in TB diagnosis, care and prevention. This could include adopting new technology and interventions, expanding the coverage and quality of existing services, intervening on the broader social and economic determinants of TB infection and disease, and implementing actions to ameliorate the economic burden of TB and TB care. Countries are developing plans to accelerate TB care and prevention, and have received global guidance to enable these efforts, including the Global Plan to End TB *(3)* and the Essentials to End TB *(4)*, which set out guidance and approaches for operationalizing the End TB Strategy.

Since 2006, the WHO Global Task Force on TB Impact Measurement has provided global oversight to ensure that assessments of progress towards global TB targets and milestones are, as far as possible, rigorous, robust and consensus based *(5-7)*. Until 2015, the focus was on targets set within the context of the Millennium Development Goals (MDGs) and the Stop TB Strategy (2006–2015). Since 2016, the focus has been on the targets and milestones of the SDGs and the End TB Strategy. In 2016, the Task Force also agreed on a new strategic area of work called "Analysis and use of TB data", which aims to support countries to improve their analysis and use of TB data for policy, planning and programmatic action. This strategic area of work includes analyses of TB-related inequalities; projections of disease burden and intervention impact; and provision of guidance, tools and capacity-building. As part of this new area, the Task Force is committed to the ongoing improvement of model-based policy analysis as a tool for strategic planning and budgeting.

1.2 Rationale for modelling

Mathematical models describe a mechanistic relationship between the actions undertaken by TB programmes to combat TB and the consequences of these actions. The consequences can include changes in summary health outcomes such as disability-adjusted life years (DALYs) averted or life years saved, measures of service use, trends in TB incidence and mortality, economic burden and budget impact. Mathematical modelling can incorporate a wide range of evidence such as clinical evidence on disease natural history, routine reporting data describing health programme performance, and economic data on costs and budget limits. It can then synthesize these inputs to estimate outcomes that would be expensive or impractical to assess empirically. This is particularly true for TB policy, where the benefits of an intervention typically extend beyond the set of individuals who receive the intervention, and are realized over a long period. When based on strong empirical evidence, modelling can be thought of as an approach for principled extrapolation, providing an understanding of how policy choices will affect future health and economic outcomes. Clearly, mathematical modelling can be a useful tool for informing national and subnational TB policy-making, programme planning and resource mobilization.

Sometimes a choice will need to be made between modelling and empirical studies, but generally these two forms of enquiry should be seen as complementary – without good empirical data, modelling is unlikely to provide accurate predictions, and without modelling it can be hard to know the exact implications of empirical findings.

1.3 Demand for modelling

It is becoming increasingly common for countries to use modelling to evaluate TB policy options, because of the increasing attention of local and international stakeholders on what it will take to achieve the End TB Strategy targets, and the need to make efficient choices (within the resource limits available) among the increasing range of TB policy options. New diagnostic and treatment technologies are becoming available (8–10), and modelling can be used to understand how these technologies can best be incorporated into programmatic efforts.

A survey by the TB Modelling and Analysis Consortium[1] (TB MAC) of groups providing technical assistance for TB modelling indicated that, by January 2018, more than 20 low- and middle-income countries across the WHO regions of Africa, the Eastern Mediterranean, Europe, South-East Asia and the Western Pacific had used modelling to inform applications to the Global Fund to Fight AIDS, Tuberculosis and Malaria (Global Fund), and in the development of national strategic plans and

[1] See www.tb-mac.org

other domestic funding applications. A notable example comes from South Africa, where modelling evidence supported the financing and allocation of a TB budget of R 500 million (US$ 40 million) *(11)*. As experience progresses, modelling is likely to become a more routine part of TB monitoring and evaluation workflows, which in turn will feed into funding applications.

1.4 Current challenges

As experience with country-level TB modelling has grown, several challenges have become evident:

- limitations in the data and evidence available to inform modelled analyses;
- limitations in the ability of models to represent complex policy scenarios, such as targeting of risk groups not represented in existing models;
- difficulty in anticipating factors that could negatively affect the outcomes of modelled policy scenarios, particularly those that involve novel interventions or aggressive expansion of existing services;
- differences in the modelling and estimation approaches taken by modelling teams, with the potential that different models could produce different policy advice, despite having the same country context and policy question;
- scarcity of human resources (globally and within high-burden countries) to meet the demand for modelling technical assistance, and lack of information for country TB programmes on what modelling support is available; and
- differences in the level of experience, understanding and expectations of the modelling process by in-country stakeholders and international funders; and, related to this, differences in the confidence placed in modelled analyses by local and international stakeholders.

Studies that have compared multiple models have found substantial variation between modelling results, even when they are investigating standardized policy scenarios *(12–15)*. Modelling is often used to forecast the impact of policies that are more aggressive or implemented at higher coverage than previously observed in routine programmes, and this need to extrapolate beyond current programmatic experience introduces much greater uncertainty into modelling results. Variation in modelling outcomes has consequences for decision-making, with the ordering of policy options by cost–effectiveness criteria differing among models *(12, 15)*. Further limitations in the robustness of model predictions may be observed in countries with weak TB surveillance data, where new data from cross-sectional TB prevalence surveys can result in significant changes to estimates of disease burden. These revisions to the understanding of recent and current epidemiology can alter future disease projections and potentially influence policy choices.

Box 1.1 summarizes the points to consider when deciding whether using a model is appropriate in a particular situation.

1.5 Existing guidance

Despite the increasing role of TB modelling, there are currently no formal guidance documents for NTPs, modellers and international partners on how to use TB models to support country-level decision-making. Several guidance documents exist in related fields, often separated into guidance on specific methodological domains; for example, epidemiological modelling, costing and economic modelling, and algorithms for identifying optimal budget allocations. The most notable contributions include recommendations by the task force of the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) *(16–22)* and recently developed reference evaluation *(23, 24)* and costing *(25)*. Relevant disease-specific guidance includes contributions from the fields of HIV *(26, 27)* and human papillomavirus (HPV) *(28, 29)*, and recent TB-specific guidance focused on the use of latent infection treatment for immigrants in low-burden settings *(30)*. These documents were used to inform the guidance outlined here.

1.6 This guidance

This guidance document is designed to address the needs outlined above; that is, an increased demand for model-based policy evaluation, concern about observed heterogeneity in results, and a desire to see more transparent links between modelled evidence and the empirical data that support them. It describes how mathematical modelling can be used to help country TB stakeholders make decisions, and it includes guidance on modelling approaches, use of data, reporting of results and expectations for various actors throughout the process.

The guidance is organized as a set of 10 principles (**Chapter 3**). Each principle is accompanied by several "good practices", which suggest concrete steps that could be taken to operationalize the principles. This is followed by a discussion of the roles and responsibilities of various actors in the modelling process, as well as how the principles align with particular activities in a typical modelling application (**Chapter 4**).

As a separate but complementary work-package to this guidance document, aimed at a similar audience, TB MAC has worked with modelling groups currently engaged in providing technical assistance to countries to develop a catalogue[1] that provides detailed information on the capabilities, approaches and history of both the models and the modelling teams.

[1] See https://docs.google.com/spreadsheets/d/1vEDYkXJbMhftWDojnWOuVDbH6h9__Jezg0xsqH5MfJo/edit#gid=287565855

BOX 1.1 ■ **When to use a model**

Modelling can provide a logical framework for projecting TB burden and budget requirements, and assessing the consequences of different policy options. In that role, models can add substantial value to NTP planning and prioritization, advocacy efforts and decisions on donor funding. However, a formal modelling exercise will not be required to answer all questions around TB policy and programme strategy. Instead, modelling should be considered alongside other approaches used to answer policy questions, including direct extrapolation from empirical studies conducted in the setting, generalizing from similar programmes or countries, and expert opinion.

If the goal is to predict future health outcomes or resource needs, any approach that is used will involve important assumptions. Although simpler approaches may appear to require fewer assumptions, this may be because assumptions are not explicit. For example, predicting the outcomes of a programme by directly extrapolating research study results can make strong assumptions that health burden, care-seeking behaviour and the capabilities of health service providers are similar between the research study and routine health services. In this circumstance, a formal model may allow future health outcomes to be predicted with more realistic assumptions. However, to answer many programmatic questions it may not be desirable to predict long-term health outcomes. For example, to identify the best approach to improve treatment completion it may not be necessary to estimate the impact on distal outcomes such as cure rates and survival; rather, it may be sufficient to assume that improvements in treatment completion will improve these other outcomes proportionally.

Compared to other approaches, a formal modelling study will typically require more time and effort to undertake; also, it may require sustained engagement from local stakeholders if it is to generate useful policy advice. Given the costs and effort required for modelling, this approach is most likely to be useful where:

- decision-makers are considering an important policy decision (i.e. one that has substantial consequences for programme budgets or health outcomes, or that would restrict future policy options);
- policy options need to be considered in terms of their impact on long-term health and economic outcomes, rather than more proximal outcomes that could be estimated using simpler methods;
- there is adequate funding, time and technical capacity to implement the modelling application; and
- there is strong engagement by relevant decision-makers, including willingness to commit the time to scrutinize modelling assumptions and scenarios, and to act based on modelling results.

CHAPTER 2

Development process, scope and target audience

2.1 Process and stakeholders

Motivated by the growing role of mathematical modelling in TB policy-making, and the apparent heterogeneity in modelling approaches and results, TB MAC was asked to develop guidance for country-level TB modelling. TB MAC is a modelling consortium funded by the Bill & Melinda Gates Foundation to provide coordination and technical assistance for TB modelling, under the oversight of the WHO Global Task Force on TB Impact Measurement. This guidance document has been developed by TB MAC in collaboration with key global stakeholders including WHO, the Global Fund, the Bill & Melinda Gates Foundation, the Stop TB Partnership, the World Bank and the United States Agency for International Development (USAID).

An initial outline of the document was prepared by a small writing committee (Nicolas A Menzies, C Finn McQuaid, Gabriela B Gomez and Rein MGJ Houben) and reviewed by a group of 30 expert stakeholders, including TB modellers, country users of TB models, and donors and advocates. Suggestions from these stakeholders were incorporated and a full draft of the guidance was developed. The draft was reviewed by the TB MAC committee and members of the WHO Global TB Programme for further comment. Following additional revisions, the draft guidance was presented and discussed at the TB MAC/WHO Task Force 2017 annual meeting in Glion, Switzerland (18–22 September 2017), where comment was invited from a wider stakeholder group, including modelling groups, international stakeholders and funders, and other technical experts. Further review and input was provided after this meeting by country stakeholders and technical experts, and the final draft of this guidance was reviewed and endorsed by the WHO Global Task Force on TB Impact Measurement in May 2018.

Individuals providing review and input into this guidance are listed in the **Acknowledgements** section.

2.2 Scope

The guidance focuses on the use of mathematical models to support national TB policy and planning, including applications to funding agencies such as the

Global Fund, USAID and the World Bank. It covers both the epidemiological and economic aspects of modelling, to capture the considerations that typically arise as part of projecting future epidemiological outcomes, evaluating the consequences of competing policy options, cost estimation, and analyses of cost–effectiveness and allocative efficiency. The scope of the guidance also includes issues related to how models are used to support country decision-making. Extending the scope of the guidance beyond the technical features of the models is deliberate, because the utility of modelling for country-level decision-making is greatly influenced by how the modelling tools are applied and integrated into the process of policy identification and comparison.

The scope described above does not encompass all issues that will arise in the conduct of TB modelling more generally (e.g. modelling not explicitly linked to national planning and budgeting). However, many of the approaches promoted in this guidance document will be generalizable to other areas of TB modelling. More detailed guidance on particular aspects of policy evaluation is available in other documents, such as iDSI's reference case for economic evaluation *(24)*. This TB modelling guidance should be read in conjunction with other relevant guidance documents, as well as any additional criteria prescribed by funders or other stakeholders in the modelling process.

2.3 Target audience

The target audience for this document is the individuals who build or apply models for country-level TB decision-making. The content of this guidance is also relevant for other participants and stakeholders in country-level TB modelling efforts, including policy-makers, technical experts and other members of the TB community in affected countries; international funding and technical partners; and individuals and organizations engaged in supporting TB policy-making. For modellers, this guidance suggests approaches that can improve the quality, relevance and timeliness of modelling work undertaken to support country-level planning. For non-modellers, it describes issues to consider when engaging modelling technical assistance to support a planning process or evaluate policy options, contributing to a modelling exercise or reviewing the results of modelled analyses.

CHAPTER 3

Principles and good practices for country-level TB modelling

This chapter describes principles and good practices for country-level TB modelling. The principles do not represent sufficient conditions for achieving valid modelling results; however, if adopted they could improve the reliability, transparency and usefulness of modelling results for TB policy-making. A summary of the principles and good practices is provided in **Table 3.1**.

Most of the principles and practices summarized in **Table 3.1** and explained in more detail in the rest of the chapter serve three higher-level goals:

- that model-based policy evaluation makes the best use of available evidence;
- that modelling is incorporated into policy-making in a way that clearly expresses the strengths and weaknesses of the modelled estimates; and
- that the modelling supports (rather than replaces) policy-making as a deliberative, country-led process.

Although the principles and practices described in this document will not provide an answer to all of the questions that arise in the context of a modelling exercise, they do address the major questions common to most country-level TB modelling applications. Several short case studies are also provided as real-world examples of how the principles apply to modelling applications, and the roles and responsibilities of various stakeholders are discussed in **Box 3.1**.

TABLE 3.1 ■ **Summary of principles and good practices for country-level TB modelling**[a]

PRINCIPLE	GOOD PRACTICE	ACTOR			
1. Relevance: Modelling should assess relevant policies and outcomes	1.1 Decision-makers, policy questions, constraints, outcomes and perspective should be determined before modelling begins	⚖	📊	🖥	
	1.2 A clear description of policy scenarios should define all actions to be modelled	⚖	📊	🖥	
2. Realism: Modelling should consider implementation challenges and examine requirements for policy success	2.1 Realistic assumptions should be made about policy costs and effectiveness		📊	🖥	
	2.2 Analyses should consider the additional costs of service expansion as well as any effect on existing services		📊	🖥	
	2.3 Where there is little prior experience of policies, sensitivity analyses should be conducted, and results appropriately labelled as speculative			🖥	
	2.4 The modelling process should remain objective		📊	🖥	$
	2.5 Assumptions and evidence for the pace and success of implementation should be documented		📊	🖥	
	2.6 Capacity limitations should be appropriately included in the analysis	⚖	📊	🖥	
3. Appropriateness of model structure: Model design should be justified in terms of the policy questions being considered and avoid unnecessary complexity	3.1 The model used should represent major mechanisms generating TB outcomes in the given setting			🖥	
	3.2 Major structural decisions in the model should be justified			🖥	
	3.3 Model choice should be based on the appropriateness to the setting, evidence, policies and outcomes in question			🖥	
4. Consideration of all evidence: Modelling should consider all available evidence relevant to the decision problem	4.1 A review of all pertinent evidence should be carried out		📊	🖥	
	4.2 Evidence should be checked for quality and appropriateness		📊	🖥	
	4.3 Conflicting evidence should be investigated		📊	🖥	
	4.4 Routine data should be checked for appropriate use		📊	🖥	
	4.5 Decisions informed by expert opinion should be validated where possible		📊	🖥	
	4.6 The implications of parameter uncertainty on results should be investigated		📊	🖥	
	4.7 Model calibration should be reported in full		📊	🖥	

PRINCIPLE	GOOD PRACTICE	ACTOR			
5. Validation: Results should be compared to evidence not used for model parameterization or calibration	5.1 Models should avoid broad claims of validity and actively test performance				
	5.2 Model results should be checked against local epidemiology and health service characteristics, as well as general TB epidemiology				
	5.3 Model sensitivity to assumptions should be checked				
	5.4 Results should be compared to other modelling results or empirical assessments where possible, or through consultation with stakeholders				
	5.5 Rates of decline in burden should be compared with historical evidence of limits in rates of decline				
6. Informativeness: Modelling should report results for a wide range of outcomes	6.1 Analyses should report summary measures of health benefit (e.g. DALYs averted, QALYs saved)				
	6.2 Models should additionally report policy consequences for a wide range of epidemiological and programmatic outcomes				
	6.3 Analyses should disaggregate total cost estimates into categories relevant for budgeting (e.g. by payer, cost category and year)				
	6.4 Analyses should investigate the impact of different time horizons				
7. Transparency: Reporting should include a description of supporting evidence, limitations, sensitivity analyses and conflicts of interest	7.1 Details of model structure and implementation should be made available in technical documentation				
	7.2 Policy and baseline scenarios should be fully described				
	7.3 A non-technical description of uncertainties, limitations, evidence sources and validation should accompany results				
	7.4 In contentious contexts, additional efforts should be made to seek engagement and agreement on the modelling approach from all important stakeholders				
	7.5 Conflicts of interest should be identified, managed and explicitly stated				
	7.6 An external review of the modelling analysis should be conducted where possible				

PRINCIPLE	GOOD PRACTICE	ACTOR			
8. Timeliness: Modelling should provide results in time for decisions to be made	8.1 Planning should be conducted to ensure that results can be provided when they are required, including review/revision of scenarios and assumptions	⚖	📊	💻	$
	8.2 If the modelling process is curtailed in order to meet a deadline, drawbacks of this should be described			💻	
9. Country ownership: Modelling should be conducted through participation with local stakeholders	9.1 Full engagement with local stakeholders should be gained	⚖	📊	💻	$
	9.2 Plans to increase country capacity should be implemented where possible	⚖	📊	💻	$
	9.3 Country input at each stage of the modelling process should be enabled	⚖	📊		
	9.4 Modelling should be planned in the light of existing efforts in research, evaluation and surveillance		📊	💻	$
	9.5 Choice of modelling technical assistance provider should be determined by ability to meet decision-maker needs	⚖	📊		$
10. Iteration: Modelling should be an iterative process, and reconsidered given new evidence	10.1 Stakeholders should evaluate initial versions of the modelling approach, policy scenarios and results, and these should be revised if needed	⚖	📊	💻	$
	10.2 The sensitivity of the model to new evidence should be described		📊	💻	
	10.3 The validity of model projections should be reconsidered if early programmatic data show assumptions to be incorrect		📊	💻	

DALY, disability-adjusted life year; QALY, quality-adjusted life year; TB, tuberculosis

[a] The "Actor" column suggests the lead actor(s) for each practice; that is, the individual or group primarily responsible for implementing the practice. Actors include

⚖ in-country decision-makers

📊 in-country experts

💻 modellers and

$ international funders.

Other actors may also have a role in contributing towards practices or activities, or in creating the demand for them.

BOX 3.1 ■ **Roles and responsibilities**

When used to support country decision-making, modelling commonly involves the participation of multiple stakeholders:

- *modellers*, who are deeply familiar with how the model works, but potentially less familiar with local evidence, available options and preferences;
- *other experts*, who bring expertise in a relevant content area (e.g. local epidemiology, programme characteristics, or costing and budgeting);
- *local decision-makers*, who may have less time to be involved in the process of implementing the model but have a central role in setting the parameters of the planning exercise and are deeply interested in the results; and
- in some cases, *external funders*, who can be influential in defining the role of modelling through the criteria used to evaluate funding requests.

The task of implementing many of the principles described in this document lies mainly with the modellers, but there are responsibilities for all parties. It is hoped that this guidance will help all those involved in TB modelling to make these exercises more valid and useful for country decision-making.

To more easily identify responsibilities for different stakeholders, **Table 3.1** includes a column of stakeholders, or actors, who would typically take responsibility in leading specific areas in the implementation of each good practice. Other actors may also have a contributory role, or a role through the creation of demand.

3.1 Principle 1 – Relevance

Modelling should assess the policies and outcomes relevant to the country context and decision being made. Without good engagement between those involved in planning and resource allocation, policy-makers, partners and analysts, it is all too easy for modelling to evaluate strategies that differ in important ways from those that are being considered by decision-makers. Where a pre-existing model is used for a new planning exercise, the model may be insufficiently tailored to the local context, or strategies may be excluded from consideration because they are not already built into the model. Ideally, the modelling exercise can be useful in shaping the policy scenarios being considered and identifying outcomes of interest. For example, the specificity required to parameterize a model can force

In practice: Relevance (Principle 1)

■ During the application of a model to multiple countries, it became clear that there were important differences in the extent to which the quality of care in the private sector was an issue. To make the model relevant to different settings, the modelling team consulted with each of the country programmes, to ensure that assumed parameters were applicable to each setting.

participants to think through the details of how a policy or new intervention would be implemented, the mechanisms through which it would affect costs and health outcomes, and how these should be summarized to inform the decision.

3.1.1 Good practices (Principle 1 – Relevance)

GP1.1. The initial task in a modelling exercise is to define the decision problem and the question or questions that need to be answered. This involves scoping the following:

- Who is making the decision? This could be the NTP, ministry of health or a subnational government entity.
- What is the question or questions to which the decision-maker would like an answer?
- What are the constraints on the policies or interventions that can be chosen (e.g. a fixed budget cap, or only allocating funding within part of the TB portfolio)?
- What are the candidate policies or intervention scenarios to be considered? These could be defined using sources such as stakeholder opinion, national strategic documents or WHO policy guidance.
- What criteria and outcomes are to be used to compare policies or interventions?
- Is modelling the most appropriate approach to address the question or questions being asked?
- What costs are to be considered (i.e. what is the study perspective), and what is the relevant budget period?

Each of these questions should be answered before considering how modelling will be undertaken.

GP1.2. Policy or intervention scenarios to be evaluated using modelling should include a complete description of all actions required to implement the policy or interventions, sufficient to allow reasonable judgments to be made about the plausibility of the assumptions and the resource requirements for implementation.

3.2 Principle 2 – Realism

Modelling should explicitly consider implementation challenges that may reduce the effectiveness or increase the costs of interventions when introduced into routine practice, and should examine the plausibility of assumptions required for policy success. Modelling is often called upon to evaluate novel interventions, or proposals to expand the coverage or quality of routine services above current levels. For these scenarios, there is generally less

In practice: Realism (Principle 2)

During a country visit, discussions between the modelling team and staff from the NTP highlighted that screening protocols did not reflect the reality of implementation, with substantial variation found. Through triangulation with data from other national modelling efforts, and agreement with local experts, model assumptions were made that reflected actual practice, including barriers to implementation and associated time implications.

information about their effects and costs (compared with established interventions) in typical programmatic settings. This can lead to overly optimistic projections of the effectiveness or cost–effectiveness of proposed policies or intervention scenarios, particularly when initial evidence is obtained in high-capacity clinical settings or for subpopulations where effect sizes are likely to be larger, or when there is external pressure for the modelling to "be ambitious". Historical experience is likely to be the best starting point for modelling assumptions about the pace and success of implementation.

3.2.1 Good practices (Principle 2 – Realism)

GP2.1. Policy or intervention scenarios should make realistic assumptions about the likely effectiveness and costs of policies or interventions in the settings in which they will be introduced, as well as the pace and process of implementation. This will probably include imperfect compliance with details of the policy or interventions (e.g. as presented in clinical guidelines) by providers, and low uptake or adherence by the intended beneficiaries.

GP2.2. The resources required to expand service provision can be substantially different from the current average cost of routine services. Where scenarios involve increases in intervention coverage, cost analyses should account for any additional activities or investments required to expand services, as well as any potential economies (or diseconomies) of scale associated with changes in service volume.

GP2.3. For policies or interventions with which there is little experience of what to expect in routine programmes, it is important to conduct sensitivity analyses and investigate situations that would lead to substantial attrition of impact, harmful externalities or increased costs. Similarly, it is useful to investigate scenarios that allow for incomplete or delayed adoption. If the empirical implementation evidence is weak or absent, results should be clearly labelled as speculative.

GP2.4. One use of modelling is to generate evidence to advocate for specific policies, interventions or increased funding levels. However, if analytic choices are made with the intention of promoting a particular outcome, this can lead to

misallocation of funding and a loss of credibility for modelling as a policy input. Therefore, preferences for a particular policy, intervention scenario or modelling outcome should not be allowed to influence analytic choices, such as assumptions about intervention effect sizes or uptake. If a modelled scenario does involve optimistic or contestable assumptions, these should be highlighted in the results.

GP2.5. Given the importance of implementation to success, the assumptions made about the pace and success of implementation should be documented, as well as the evidence basis for these assumptions.

GP2.6. Where capacity limitations are known to exist, it is preferable for these to be represented in the analysis. This can be achieved either by modelling the negative impact on other services that would result from expanding one programmatic area, or by including constraints in the analysis such that use of a particular resource cannot go above a known level. Ideally, analyses would also consider the costs and benefits of efforts to relax capacity constraints.

3.3 Principle 3 – Appropriateness of model structure

The model design should be justified in terms of the policy questions and local context being considered – the structure should be sufficiently detailed to represent the mechanisms generating outcomes but avoid unnecessary complexity. Model development commonly involves numerous decisions about model structure, dealing with how to represent the population affected by a particular policy or intervention, and how to describe their transition through demographic and epidemiological processes, and access to or receipt of health care. These choices balance the following conflicting priorities:

- faithfully representing the process being modelled, which commonly leads to more detailed modelling approaches, such as greater heterogeneity of the modelled population, or more complicated functions describing health state transitions or the relationship between implemented activities and outcomes; and

In practice: Appropriateness of model structure (Principle 3)

During application of a model in countries in Asia and Africa, it became clear that the model needed an appropriate structure to capture the complete screening population, including those who did not have TB and were at risk of being misdiagnosed (i.e. false positives) with TB. With this appropriate structure, the model was able to provide a more complete impression of resources needed (e.g. people screened) and potential negative consequences of proposed screening programmes.

- developing a model whose processes are transparent, understandable and interpretable to both the modeller and the modelling audience, which is often better served by simpler, more parsimonious modelling approaches.

Some structural choices will promote both of these aims simultaneously, but most will involve a trade-off between realism and parsimony. Moreover, the decision to add more detail on a particular part of the model will not necessarily improve the validity of the results, because as the overall complexity of a model increases, it can become more difficult to explain unexpected model results and identify errors. Similarly, given the constrained resources and short time frame commonly available for modelling applications, if the model runs slowly and requires substantial computing resources, this can limit the opportunities to fully investigate parameter uncertainty, assess all relevant policy scenarios and iteratively improve the analysis through feedback from modelling stakeholders.

3.3.1 Good practices (Principle 3 – Appropriateness of model structure)

GP3.1. Models should be able to represent the major mechanisms generating TB outcomes in a particular setting. For example, in settings with high levels of TB–HIV coinfection, models should be able to represent the influence of HIV-associated immune suppression on TB natural history, as well as the impact of current and planned future levels of antiretroviral therapy coverage. Similarly, for settings with high proportions of drug-resistant TB, models should consider the influence of drug resistance on health outcomes and costs. These mechanisms can also describe programme functioning. For example, in analyses designed to examine improvements in case detection, it will generally be appropriate to model the full TB care cascade, rather than assume a single rate of treatment initiation for individuals with undiagnosed active TB.

GP3.2. Major structural decisions in the model should be justified in comparison to alternative approaches, and any limitations of the chosen structure clearly described. Where possible, alternatives to the model structure should be tested, to understand their implications for model results. Formal comparisons of different models or modelling approaches can be undertaken for important policy questions where structural uncertainty is a concern, although these comparisons are unlikely to be feasible in the context of a typical application.

GP3.3. If multiple models are available for use in a given analysis, the choice of model should be based on its relative ability to:

- represent key features of TB epidemiology, health service interactions and resource use in the setting of interest;
- reflect the available evidence to inform model structure;

- represent risk groups being considered by the policies or interventions of interest;
- represent the mechanisms by which the policies or interventions of interest will have an effect; and
- produce the outcomes of interest to decision-makers (including both costs and health outcomes).

3.4 Principle 4 – Consideration of all evidence

Modelling should consider all available evidence relevant to the decision problem. Mathematical models specify a sequence of relationships that link the actions described under a policy or planning scenario to the health and economic outcomes of interest. Typically, many different sources of evidence are required to parameterize these relationships, and errors in any of these parameters will affect results. Although there will be finite resources (including time) available to collate inputs, all key data and evidence should be identified and incorporated to produce valid and accurate results. Where there is substantial uncertainty in key parameter inputs, it should be thoroughly investigated, and the implications of this uncertainty for conclusions drawn from the analysis should be reported alongside the main analytic results. Adjusting parameter values so that model predictions are consistent with observed data (model calibration) can improve the validity of future projections and increase confidence among the consumers of modelling results. However, calibration must be undertaken carefully to avoid overfitting and acknowledge potential biases in calibration data.

In practice: Consideration of all evidence (Principle 4)

During a review of evidence to inform modelling related to the introduction of preventive therapy for contacts and active case finding (ACF), the modelling group identified important differences in the type of evidence available for these two interventions. Specifically, epidemiological evidence about the efficacy of ACF was available from cluster randomized trials, whereas evidence about the efficacy of preventive therapy was available from clinical studies at the level of individuals. The modelling report clarified the differences in the type of evidence available, and the limited evidence regarding the effectiveness of both interventions under programmatic conditions.

3.4.1 Good practices (Principle 4 – Consideration of all evidence)

GP4.1. Preparation of a model to answer a particular question should be accompanied by a thorough review of the evidence pertinent to the policy or planning scenario being evaluated. Although a new systematic review and meta-

analysis is unlikely to be feasible for all model parameters, it can be considered for influential model inputs, where existing reviews are insufficient.

GP4.2. All evidence that might be used for modelling should be reviewed in terms of its quality (e.g. strength of study design and precision of measurement) and appropriateness for the given application. Often, there is a need for trade-offs between the strength of study design and the local relevance of data. Where the use of evidence requires generalization from a different setting or an intervention that is related but different, the assumptions required to do so should be made explicit, so that the consumers of modelling results can judge their plausibility.

GP4.3. Inputs should be reviewed to assess whether there are any conflicts between different data sources; if conflicts exist, they should be investigated. If conflicting sources of evidence are available as model inputs (e.g. different estimates of the current TB disease burden), it can be useful to estimate results separately under both sets of assumptions. If outcomes of interest (typically, the incremental effects of policies, or planning or intervention scenarios relative to each other) are sensitive to the choice of inputs, this uncertainty should be highlighted in the results.

GP4.4. Modelling commonly makes use of routinely collected data (e.g. monitoring indicators and routine surveillance) for parameterization and calibration. In many settings these data can be incomplete, be affected by various biases or measure outcomes that differ from those being estimated by the model. When using such data, it is important to carefully examine how the data were generated to make sure they are used appropriately.

GP4.5. Expert opinion commonly plays a role in applied modelling exercises. Where expert opinion is used, efforts should be made to corroborate the modelling decisions informed by expert opinion; for example, through comparisons with data-derived values from different settings. For influential parameters it may be prudent to seek data from multiple experts using formal elicitation techniques, and account for the variance in opinion.

GP4.6. Even with an exhaustive review of available evidence, there is likely to be substantial uncertainty around multiple model parameters. This uncertainty should be investigated to understand the implications for model results. Two common approaches for doing so are:

- *deterministic sensitivity analyses* for individual parameters or groups of parameters, which can reveal how the model reacts to different assumptions about specific inputs; and
- *probabilistic sensitivity analysis* (PSA, or second-order Monte Carlo simulation), whereby uncertainty in all input parameters is propagated through the model to provide information on the possible distribution of model results.

These approaches provide different information and are not mutually exclusive. Deterministic sensitivity analysis can help stakeholders develop intuition about how the model works, and identify parameter combinations that would lead one policy to be preferred over another. PSA can provide information on the aggregate uncertainty in model results, and thus allow decision-makers to make an informed judgment about the risks associated with using uncertain predictions to inform programme planning. PSA results must be interpreted carefully, because the many simplifying assumptions involved in an analysis can artificially restrict the range of uncertainty, and the actual uncertainty around model predictions may be greater than that estimated by PSA.

GP4.7. Model calibration can be accomplished by several methods. Manual calibration can yield reasonable results when there is a single parameter or a small number of parameters to be fitted. However, this approach can be challenging when the number of parameters is larger, in which case, automated methods may be preferred. Where calibration is undertaken, results should be accompanied by a report of the fit of the model to the calibration data and a description of the methods used to achieve calibration.

3.5 Principle 5 – Validation

Where possible, model results should be compared with evidence not used for model parameterization or calibration, to understand the consistency of modelling results with other evidence. Given the complexity and number of assumptions involved in mathematical models, it is difficult to confirm that the model will produce valid results by scrutinizing model inputs and structure. Further confirmation that a model is operating correctly can be gained by comparing model results to other evidence; examples include the results of empirical studies or similar modelling efforts, or the experience of experts familiar with the subject matter. None of these comparisons can fully guarantee that the results of a particular analysis are valid; instead, they either provide confirmation that some aspects of model predictions are consistent with external data, or reveal conflicts for further investigation.

3.5.1 Good practices (Principle 5 – Validation)

GP5.1. Although validation is important in mathematical modelling, it is unusual to have an opportunity to validate the outcomes of interest, such as total budget impact, DALYs averted or incremental cost–effectiveness ratios for competing policies or for planning or intervention scenarios. Moreover, model validation undertaken in one setting and to answer one particular question does not necessarily imply that the results will be valid for other settings and questions.

In practice: Validation (Principle 5)

In another recent modelling application, multiple models were available to be used. By fitting several models to the same epidemiological setting and comparing results, modellers were able to identify inconsistencies for greater scrutiny. In turn, this led to refinements in the modelling approach and interpretation of input data.

Therefore, modelling should avoid general claims of validity, and should actively seek to test model performance in each new application.

GP5.2. Where possible, model results should be checked to ensure that they reproduce known features of local disease burden and health service characteristics (e.g. TB case notifications, results from TB prevalence surveys, treatment outcome data and TB programme budgets), as well as general features of TB epidemiology (e.g. the probability and timing of active disease for individuals with latent TB infection [LTBI]).

GP5.3. Sensitivity of results to major assumptions should be identified, discussed with modelling stakeholders and reported with the results. As far as possible, this process should consider structural as well as parametric assumptions.

GP5.4. Where possible, results should be compared to other modelling results or to empirical assessments that have examined the same question or questions. These comparisons are unlikely to be exact, and comparisons between the results of different models will be less informative if the models themselves are similar. However, even if such comparisons are imperfect, they can help to corroborate findings in situations where rigorous validation is difficult to achieve. Results may also be validated through consultation with local subject-matter experts.

GP5.5. When modelling examines scenarios that are radically more aggressive than current approaches to TB prevention and care, this can challenge the appropriateness of modelling assumptions, even though the assumptions might be reasonable for evaluating less aggressive scenarios. In this context, it is useful to check the rates of decline in TB burden (i.e. LTBI prevalence, TB incidence and TB mortality) suggested by the model with historical evidence about the maximum plausible rates of decline. For example, the fastest national decline in TB incidence achieved in the past has not exceeded about 10% per year.

3.6 Principle 6 – Informativeness

Modelled analyses should report a rich set of results describing policy consequences for a range of outputs and outcomes, to provide a deeper understanding of the scenarios being modelled and model functioning. TB

policy or planning options are likely to have implications for a range of different outcomes of interest to decision-makers. For example, an intervention that improves the quality of TB care in marginalized communities will most immediately reduce morbidity and mortality for individuals with active TB disease, but could also have implications for *Mycobacterium tuberculosis* transmission and TB incidence, trends in TB drug resistance and the socioeconomic distribution of TB burden. In a conventional economic evaluation, these various outcomes are combined in a single measure of health benefit (e.g. DALYs averted or deaths averted) to summarize the overall health implications of each of the alternative options being considered. Calculating a single summary metric facilitates the process of identifying the optimal choices (e.g. policies that maximize health benefits for a given budget envelope).

Nonetheless, these summary measures may not capture all health outcomes of interest to decision-makers. For example, aggregate measures such as DALYs do not describe the distribution of health benefits across the population, yet distributional information will be relevant if reducing inequality is a policy goal. Similarly, changes in trends in TB drug resistance may have little impact on health outcomes over the time frame of the analysis, but will affect the long-term viability of TB treatment options, a key concern for TB programmes.

In practice: Informativeness (Principle 6)

During a multicountry modelling exercise to examine the impact of radically expanded TB programmes, it became clear that epidemiological outcomes alone were not sufficient to judge the plausibility of modelled strategies To allow county programme experts to judge the feasibility of a strategy, models were used to predict additional outcomes describing the changes in programme performance required to achieve greater impact; examples of such changes are numbers needing to be screened and improvements in cure rates. In some cases this led to the original strategy descriptions being judged implausible; in such cases, strategies were revised to be more realistic.

Reporting results for multiple outputs and outcomes (in addition to summary health measures) can provide a more complete description of the consequences of the different options being considered. Moreover, providing a rich set of results to decision-makers can help them to develop a deeper understanding of how policies or interventions work, how different outcomes relate to each other, and the timing of effects.

Similar considerations apply to resource needs estimates generated by models. Although an aggregate estimate of resource implications is often required, it is also useful to provide cost estimates disaggregated according to when resources will

be needed, what budget they will be funded from, and how they compare with existing health system budgets and expenditures.

Finally, reporting a more informative set of results – for example, describing the intermediate outcomes between inputs and health impact – can provide additional reality checks, allowing modelling participants to confirm that anticipated programme changes are plausible.

3.6.1 Good practices (Principle 6 – Informativeness)

GP6.1. Modelled analyses should report the effects of policies or planning or intervention scenarios on a summary measure of health benefit – such as DALYs averted or quality-adjusted life years (QALYs) saved – that aggregate consequences for both survival and quality of life. These synthetic measures should be calculated using conventional methods, and should describe key analytic decisions such as disability weights and life tables used. Life years saved may be used to compare policies primarily aimed at averting mortality, but inclusion of changes in quality of life can allow broader comparisons.

GP6.2. In addition to summary measures of health benefit, modelled analyses should report a rich set of results describing a range of outputs and outcomes that might be relevant to decision-makers.

GP6.3. Resource needs estimates generated by modelling should disaggregate estimates of total cost or resource needs into categories that are relevant for budgeting (e.g. by payer, cost category and year), to provide a granular description of where and when resources will be needed.

GP6.4. Modelled analyses should report the relative timing of health benefits and costs produced by the model. TB interventions typically yield health benefits that are substantially lagged relative to their costs; hence, the choice of time horizon can be important. When a short time horizon is adopted, analysts should consider whether substantial consequences (in terms of both costs and benefits) have been omitted from the analysis, potentially through sensitivity analysis.

3.7 Principle 7 – Transparency

Modelling results should be accompanied by a clear description of the evidence that supports the main findings, the limitations of the modelling approach, uncertainty in modelled estimates and the sensitivity of results to different assumptions. Conflicts of interest should be avoided if possible, but where they are unavoidable they should be described explicitly. Models typically reach a level of complexity that makes their mechanisms difficult to understand for anyone lacking the time to read and review extensive

In practice: Transparency (Principle 7)

During the preparation of modelling results for use in a country application to the Global Fund, the structure of the model, and its strengths and limitations, were discussed at length with in-country stakeholders. In addition, a smaller in-country modelling team tested the key assumptions and model functionality. Opening up the "black box" led to critical questions being raised, which helped to improve model structure and documentation, and also the calibration of the model to country data.

documentation, particularly stakeholders who are less familiar with modelling methods. During the course of model development, it is common to have to make assumptions that have only weak empirical support. However, because of the sheer number of assumptions being made it is difficult for a consumer of modelling results to know which assumptions are important and which have only minor influence on the outcomes of primary interest. Despite this situation, it is critical that consumers of modelling results have the information available to understand the strengths and limitations of modelling results, any threats to validity, and which factors relevant to decision-making are considered in the model and which are not (and therefore may need to be considered separately).

The fact that modelled analyses are complicated and subject to many analytic decisions means that conflicts of interest can be particularly problematic. Conflicts may arise where a particular decision involves significant commercial, professional or other interests. If analytic approaches are chosen in order to favour a preferred outcome, this may not be apparent to a non-expert audience, or even to an expert audience aware of the range of possible modelling approaches. Therefore, important conflicts of interest among the participants in a modelling process should be identified and avoided where possible. It may not always be possible to avoid conflicts, in which case an explicit statement describing the conflicts should be presented with the results, such that the results can be evaluated in the context of this information.

3.7.1 Good practices (Principle 7 – Transparency)

GP7.1. Full details about the structure and implementation of the model should be made available through detailed technical documentation, including the parameter values used and their ranges, with a justification of values chosen. Although it is unlikely that a model would be replicated to validate the analytic results, the documentation should be detailed enough to make this possible. Clear information should also be available on any adaptations made to the model for a particular application. Ideally, computer programming code should be made

available, and the modelling team should be available to answer questions about the model.

GP7.2. A detailed description of the alternative scenarios assessed in a particular application, and how these were developed, should be produced. Many applications include a comparison with a "business-as-usual" base case, and this should also be clearly described.

GP7.3. Results reported by the modelled analysis should be accompanied by a non-technical description of uncertainties and limitations, the evidence sources supporting major assumptions, and the extent to which the model has been validated for the research question at hand. Discussion of uncertainty should ideally consider how this might affect decision-making (e.g. should major policy decisions be delayed until further studies have been conducted and more evidence is available?).

GP7.4. In situations where modelling results might be contentious, additional efforts should be made to engage all important stakeholders early in the modelling process, and seek broad review, input and agreement on draft versions of policy scenarios and results. Information should also be reported on the approach that was used to identify participants in the modelling.

GP7.5. At the planning stage of a modelling exercise, any major conflicts of interest for parties involved in the modelling should be identified, and a plan developed for managing them.

GP7.6. It can be useful to seek external expert review of the modelling approach and results. External review – either at a point when analyses can be revised, or after modelling has been completed – can help donors or local decision-makers judge the strengths and limitations of the analysis, and better understand the implications of results for decision-making.

3.8 Principle 8 – Timeliness

Modelling activities should be organized to provide results at the time they are required for decision-making. Ideally, this principle would not conflict with the other principles. However, in practice, the need to produce results quickly can reduce the opportunities to test all aspects of a model; it can also reduce the time and opportunities for stakeholders to review results, raise questions and refine scenarios.

3.8.1 Good practices (Principle 8 – Timeliness)

GP8.1. At the start of a modelling project, identify when modelling evidence is needed to support decision-making, and develop a time frame to meet that

In practice: Timeliness (Principle 8)

A country application was timed to evaluate the impact of reforming a national TB programme. The model team captured the current TB epidemic and response, as well as alternative response scenarios, using findings from a pilot project on patient-centred care, which had recently become available. Results outlining an optimized TB response strategy were reviewed and released in time to inform a dialogue around national TB care. During this dialogue agreement was reached on key components of reform to the NTP.

target, including sufficient time for review and revision of scenarios and modelling assumptions.

GP8.2. It may be necessary to cut corners if modelling results are required urgently to meet a particular decision-making deadline (e.g. sensitivity analyses or stakeholder engagement may be more limited). In these situations, the drawbacks of such an abbreviated process should be explicitly described.

3.9 Principle 9 – Country ownership

Modelling should be conducted with the full participation of local stakeholders at each stage of the process. Modelling is more likely to be useful and the results used when it is conducted with the full participation of relevant stakeholders. Their involvement means that modelling assumptions and modelled scenarios are more likely to be appropriate, and that results are more likely to be fully understood and considered by policy-makers when making decisions. Country ownership is not guaranteed in situations where modelling is conducted by external technical experts, and where the need for modelling and the format of the planning exercise are dictated by external funding agencies. In such situations, greater efforts may be needed to gain full engagement of all important stakeholders. In any country there will be existing initiatives for the collection and use of data to inform programme planning. Coordination with these efforts will

In practice: Country ownership (Principle 9)

In a recent country modelling application undertaken in the context of a Global Fund grant, there was a strong emphasis on country leadership and engagement from the outset. A country modelling team was created, with representation from all major organizations working on TB in the country, including the NTP, the WHO country office and the principle recipient of the Global Fund. Following training in the use of the modelling tools, the country modelling team led the planning, execution and communication of the modelling work, for both domestic and international stakeholders.

improve the quality of data available for modelling, and reduce the chance that decision-makers receive conflicting policy advice.

3.9.1 Good practices (Principle 9 – Country ownership)

GP9.1. An initial task of a modelling project is to identify and engage relevant country stakeholders. Typically, the NTP will be involved in any modelling exercise concerned with the TB response; however, it may also be helpful to include representatives of other organizations. These could include nongovernmental organizations (NGOs) engaged in providing care, patient advocacy organizations, local subject-matter experts, and local representatives of international funders and technical partners.

GP9.2. To aid model choice, the desire for in-country capacity-building should be assessed and addressed early on in the project. This could involve anything from enabling key partners in the NTP to critically examine model assumptions and results, to building the capacity needed to operate the model without external technical assistance.

GP9.3. Country input should be enabled at each stage of the modelling process. This includes parameterization and calibration (i.e. determining whether key epidemiological and cost targets are reflected satisfactorily), decisions on intervention scenarios and review of modelling results before dissemination to a wider audience.

GP9.4 Any new modelling application should be planned in the light of existing efforts in research, evaluation, surveillance and technical assistance designed to inform policy and planning.

GP9.5. If modelling is to be undertaken by an external technical assistance provider, the choice of provider should depend on their ability to meet the country decision-makers' needs. These considerations can include familiarity with the setting and questions of interest, whether the proposed approach (format for the modelling project) will produce results within the required time frame, and whether it will provide sufficient opportunities for input and critical review of modelling results. The linked catalogue[1] provides detailed information on organizations currently engaged in providing country technical assistance for TB modelling (although this is not exhaustive).

[1] See https://docs.google.com/spreadsheets/d/1vEDYkXJbMhftWDojnWOuVDbH6h9__Jezg0xsqH5MfJo/edit#gid=287565855

3.10 Principle 10 – Iteration

Modelling should involve an iterative process of engagement, and should be reconsidered in light of new evidence. Given the complexity of modelling and decision-making, an iterative process is likely to be needed for identifying candidate policies or interventions, and the evidence to describe them. Hence, the modelling approach needs to allow for iteration between adaptation of the model and evaluation of results. Once a modelling exercise is complete, the results should remain open to criticism and revision in light of new evidence, and a clear way forward to improving the process should be identified.

3.10.1 Good practices (Principle 10 – Iteration)

GP10.1. In a given modelling application there should be multiple opportunities for review of model scenarios and results by key stakeholders. Explanations should be sufficient for stakeholders to understand major analytic decisions and assumptions, and allowance should be made for analyses to be revised in light of feedback.

GP10.2. Modelling results should be accompanied by an explanation of the sensitivity of results to new evidence, research that would be useful to validate the modelled results, and findings that should trigger revision of the analysis.

GP10.3. As new policies are introduced, early programmatic data can be used to check assumptions made during modelling. If modelling assumptions are incorrect, the validity of longer term projections should be reconsidered. If necessary, model projections may be updated based on actual implementation data.

In practice: Iteration (Principle 10)

Estimates of disease burden (e.g. those from WHO's *Global TB report*) are released annually as new surveillance and survey data become available. Modelling groups have evaluated past modelling projections and results in the light of new burden estimates or data, such as prevalence surveys or inventory studies. As part of preparations for a Global Fund application, one modelling group returned to previous projections and reviewed these in the context of new prevalence survey data.

CHAPTER 4

The modelling process

Fig. 4.1 links the principles and good practices to the actions undertaken in a typical modelling application. The flowchart describes the sequence of actions and linked principles that are relevant for each particular action, and the stakeholder or stakeholders that would typically take the lead for each principle.

The first stage of the modelling process is to define the decision or problem. This includes the various aspects described under Principle 1 (**Section 3.1**), including identifying the decision-maker, and defining the policies to be compared and the outcomes of interest. An important question at this early stage is whether mathematical modelling is the right approach to answer the policy question, given the other approaches that could be used. Where modelling is decided to be the right approach, the next step is to identify important stakeholders and relevant experts, and form the project team that will collaborate on the modelling exercise. Once these have been determined, the next step is to define the time frame in which the work will be done, and how this fits into the policy and planning cycle. This leads to the choice of model used – in particular, the identification of any existing models that meet the required need. For any available models, the suitability of the model to the question, particularly with regard to model structure (e.g. whether it includes relevant risk groups, stratifications, interventions or epidemiological characteristics), should be examined. In addition, suitability of a model structure will depend on the time and labour requirements to undertake the analysis, and the ability to provide training and capacity development, if requested. In some situations, there will only be one model available for a particular application, but this does not remove the need to critically evaluate its suitability for the country context and policy questions being asked.

Once a model has been chosen, the next step is to identify the required data (e.g. burden estimates and impact and cost estimates of likely interventions), and determine how and where these data will be obtained, and what steps will be taken to address any data gaps (e.g. additional data collection, or assumptions based on expert opinion). Each of the actions described above feeds back into previous actions; hence, it is important to iteratively adapt each of the actions within this first stage.

Once the first stage has been firmly established, the next step is to identify the required resources for the work, including, for example:

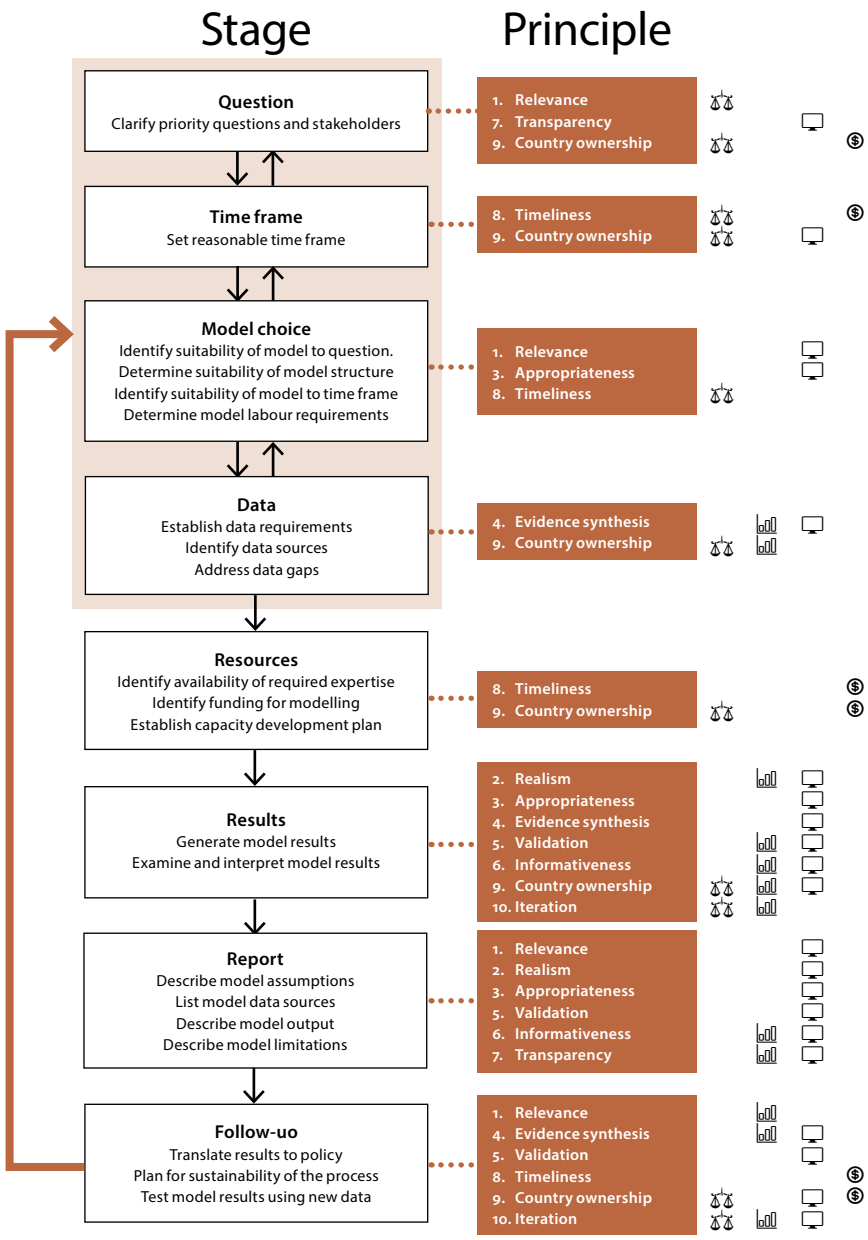
- the required expertise in terms of in-country decision-makers, epidemiologists and costing experts, as well as technical assistance;
- the availability of sufficient funding for the work, whether from in-country or an external donor; and
- a plan for development of institutional or in-country capacity, to ensure that the work can be continued in the future.

This is the point at which to formally form the modelling team, typically with an external modelling group. Once the team has been formed, the model can begin to be used to generate results, which should then be examined and interpreted by the relevant experts.

The subsequent stage, reporting of the model results, highlights the need to describe key assumptions made in the modelling, to include the sources of various data used, describe the model results and identify limitations to the modelling approach. More detail relevant to this section can be found under Principle 7 (transparency).

Finally, follow-up is needed after the reporting of model results. This includes follow-up related to the translation of results into action, helping to ensure the sustainability of the process, and testing of the model as new data become available.

FIG. 4.1 ■ **Flowchart of steps involved in a typical modelling project**[1]



[1] Also displayed are the suggested lead actors for each step in the modelling process; that is, the individual or group primarily responsible for implementing principles from a given practice. Actors include in-country decision-makers, in-country experts modellers and international funders.
Other actors may also have a role in contributing towards activities, or in creating the demand for them. Although all relevant principles are listed here, in reality, not all good practices for each principle or indeed all lead actors for each good practice will be relevant to a given step in the process. The leads listed here for each activity therefore do not match exactly with all of the leads for a given practice listed in **Table 3.1**.

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