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Evaluating cost-effective investments to reduce the burden of drug-resistant tuberculosis (TB) in Tajikistan

Findings from an Optima TB analysis, 2023

Burnet
reach for the many

Acknowledgments

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Key stakeholders

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Suggestion citation

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Abbreviations

ART	Antiretroviral therapy
BCG	Bacillus Calmette-Guérin
Bdq	Bedaquiline
BPaLM	novel all-oral 6-month regimen composed of bedaquiline, pretomanid, linezolid and moxifloxacin
COVID-19	Coronavirus disease caused by the SARS-CoV-2 virus
CSO	Civil society organization
DR-TB	Drug-resistant tuberculosis
DS-TB	Drug-sensitive tuberculosis
EPTB	Extrapulmonary tuberculosis
HIV	Human immunodeficiency virus
LTBI	Latent tuberculosis infection
MDR-TB	Multidrug resistant tuberculosis
mSTR	modified shorter all-oral treatment regimens
NGO	Non-governmental organization
NTP	National TB Protection Program of the Republic of Tajikistan
PLHIV	People living with HIV
RR-TB	Rifampicin resistant tuberculosis
SN	Smear-negative
SP	Smear-positive
TPT	TB preventative treatment
XDR-TB	Extensively drug-resistant tuberculosis

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Executive summary

BACKGROUND

Estimated tuberculosis (TB) incidence has declined in the Republic of Tajikistan, from a high of 220 estimated new infections per 100,000 population in 2002 to 78 per 100,000 in 2022 based on WHO Global TB Programme data. However, the country continues to experience high burden of Rifampicin resistant (RR) and multi-drug resistant (MDR)-TB. An allocative efficiency analysis was undertaken to estimate the optimal allocation of funding to minimize both drug resistant (DR) TB cases and TB-related deaths by 2030.

KEY FINDINGS

Recommendations

1. **Expanding TB preventive treatment for children** 0-14 is a top priority to reduce incidence of TB.
2. **The cost-effectiveness of contact tracing could be improved** by focusing on screening household contacts over repeat contacts from other settings and prioritizing screening of child contacts.
3. **Expanding community-based active case finding** is cost-effective and is recommended to reach populations with higher risk of TB infection.
4. **Shorter, all-oral regimens for treating drug resistant TB** are more cost-effective, allowing for a larger number of people to be treated for the same amount of spending, as well as having fewer side-effects and better adherence for people with TB.

Baseline

The model estimates there were 8,026 new and relapse cases of TB in 2022, of which 14% were drug resistant. In 2022 an estimated US$27.3million was spent on direct TB prevention, screening and treatment programs, of which 63% was spent on testing and 32% was spent on treatment.

Optimization of current spending

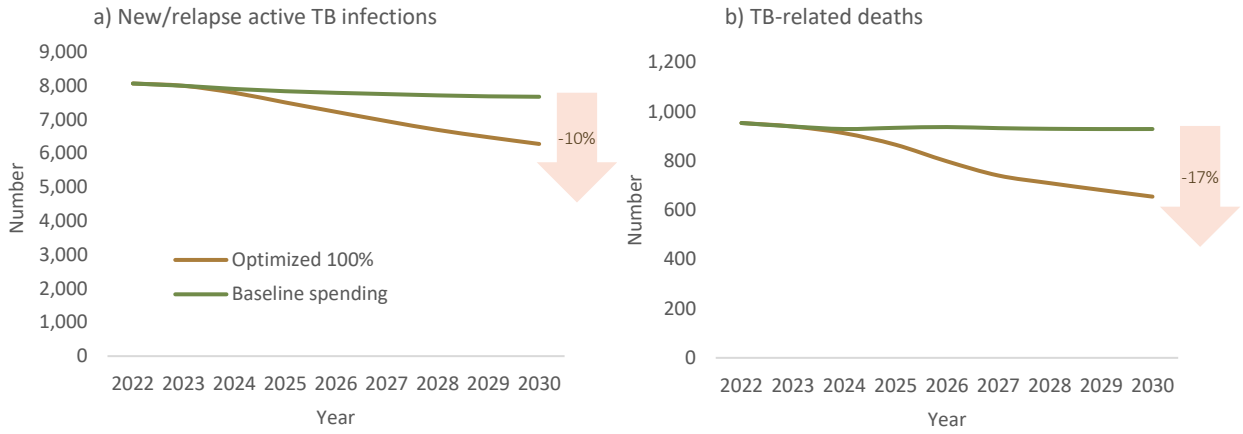
Tajikistan can improve the impact of its investment in the TB response by: prioritizing short-course MDR-TB treatment (+US$ 308,00) rather than the standard MDR-TB treatment regimens (-US$ 649,000); scaling up TPT for all children 0-14 (+US$ 6.9M); and reallocating spending from mass testing (-US$ 204,000) to prioritize more targeted active case finding among individuals at higher risk through community-based active case finding (+US$ 1.1M). Spending on contact tracing could be reduced by improving cost-effectiveness through better targeting of contact tracing with a focus on child contacts who have a higher positive yield.

Expanding active case finding in hospital and primary health care by up to 30% is advised. This is assumed to be feasible based on pre-COVID rates of screening and diagnosis, but additional interventions to increase awareness for TB testing may be necessary to achieve this.

As a result of the shorter course treatment and savings made through more targeted and cost-efficient case-finding, an additional 2343 (+33%) people could be initiated on treatment for DR-TB from 2024 to 2030 for the same amount of overall TB spending and 879 new/relapse DR-TB cases could be averted over the same period.

Projected impact

With 100% of baseline TB spending optimized, it is estimated that approximately 5,500 (-10%) new and relapse TB infections and 1,100 (-17%) TB-related deaths could be averted from 2024 to 2030 compared with if baseline spending were continued. Projected epidemic impact of optimized spending is particularly high among children given the prioritization of TB preventive treatment among children. However, Tajikistan is not projected to meet the 2030 End TB targets with current interventions and up to 150% of baseline spending.



1 Background

Overall tuberculosis (TB) incidence has steadily decreased in the Republic of Tajikistan from a high of 220 per 100,000 in 2002 to 78 per 100,000 in 2022 based on WHO-reported estimates, and Tajikistan was on track to achieve the End TB 2020 milestone (1). However, relative progress has slowed since 2015. Disruptions due to COVID-19 and pandemic response measures may have further impacted progress, and TB mortality has increased since 2020 (1-3). Tajikistan remains one of the top 30 countries for high burden of Rifampicin- (RR) and multi-drug resistant (MDR)-TB (2). In 2022, 28% of new cases and 33% of previously treated cases had MDR/RR-TB (1, 4). Key and vulnerable populations identified to be most-at-risk of TB or with poorer TB outcomes in Tajikistan include migrant workers, people with chronic disease, prisoners, and people living in poverty.

Overall treatment success for TB is 92% in Tajikistan, but 81% for MDR-TB cases on second line treatment (1). The proportion of individuals being treated with World Health Organization (WHO)-recommended shorter treatment regimens increased from 19% in 2021 to 23% in 2022. Tajikistan can procure affordable drugs through the Global Drug Facility procurement mechanism, and Government co-financing of second line drugs has been increasing since 2020 (3). Current barriers to treatment include delays between diagnosis and treatment enrollment, loss to follow up, and continued reliance on hospitalization (3).

Domestic share of funding for the TB response in Tajikistan is increasing, and in 2022 57% of funding was received from domestic resources (5). A recent grant from the Global Fund to scale-up access to HIV and TB is ending in 2023 (6). Considering the high burden of MDR-TB and scarce resources for health, an allocative efficiency analysis was conducted to estimate the most efficient allocation of TB resources in Tajikistan.

Study objectives

This Optima TB analysis aims to assess the cost-effectiveness of current and future programs for TB prevention, case finding and treatment and thereby estimate the most efficient allocation of resources for Tajikistan. Specifically, this analysis will:

1. Assess the cost-effectiveness of current and future programs for TB prevention, case finding and treatment;
2. Evaluate opportunities to improve the cost-effectiveness of TB screening, diagnosis, prevention and treatment programs to minimize the number of active MDR-TB cases by 2030; and
3. Assess how TB prevention, screening and treatment interventions should be prioritized as part of the End TB strategy to achieve 2030 targets.

2 Methodology

OVERVIEW OF OPTIMA TB MODEL

To carry out the analyses, the team used Optima TB, a mathematical optimization model applied to assess how to allocate the available resources across TB programs efficiently to maximize impact. Optima TB is a dynamic, population-based model that partitions the population by risk group including age, TB health state (for example, susceptible, vaccinated, latent TB, active TB), diagnosis and drug resistant types, and tracks people's movement among health states. The model incorporates evidence on biological transmission probabilities, detailed infection progression and population mixing patterns. A detailed illustration of the compartmental model structure is included in Appendix A, Figure A1.

To assess how incremental changes in spending affect TB epidemics and determine an optimized funding allocation, the model parameterizes relationships between the cost of TB interventions, the coverage level attained by these interventions, and the resulting outcomes (cost-coverage-outcome relations). These relationships are specific to the place, population, and intervention being considered.

Using the relationships between cost, coverage, and outcome in combination with Optima TB's epidemic model, it is possible to calculate how incremental changes in the level of funding allocated to each intervention will impact the overall epidemic indicators. Furthermore, by using a mathematical optimization algorithm, Optima TB is able to determine an optimized allocation of funding across different TB interventions.

COLLABOURATION AND STAKEHOLDER INVOLVEMENT

The analysis was a collaboration between the National TB Protection Program of Tajikistan (NTP), Burnet Institute and the Global Fund. National collaborators defined the scope of the analysis, collated national epidemiological, program and cost data, and reviewed and validated all input data, model calibration and cost-coverage-outcome relations.

POPULATIONS AND TB PROGRAM AREAS

Populations considered in this analysis were:

- Children 0-4 years
- Children 5-14 years
- Adults 15-64 years
- Adults 65+ years
- Prisoners 15+ years
- Migrant workers, male
- People living with HIV (untreated)
- People living with HIV (on ART)

In Tajikistan each year approximately 500,000 people leave to other countries for employment, predominantly as short-term season migrants (7). Male migrants account for 86% of migrant workers in Tajikistan, and this analysis only modelled male migrants workers as a separate population.

Based on available data, the following TB programs were considered in the analysis (see also Appendix A1):

Table 1. TB programs included in the Optima TB Tajikistan analysis, 2023

Prevention	TB preventive therapy (TPT) for contacts:	0-4 years
		5-14 years
		15-64 years
	TPT for PLHIV	
	BCG for children aged 0-4	
Diagnosis	Passive case finding (symptomatic screening)	
	Mass screening (school-based)	
	Mass screening (community TB day)	
	Active case finding among prisoner populations	
	Active case finding (community-based)[1]	
	Active case finding (hospital and primary health care)[2]	
	Contact tracing[3]	
Treatment	DS-TB treatment	
	MDR-TB standard treatment	
	MDR-TB shorter treatment regimens	
	XDR-TB standard treatment	

Notes: 1, Includes mobile and community-based screening delivered through non-governmental organizations; 2, May also incorporate passive case finding in health facilities; 3, Includes screening among child household contacts and screening among both adult household contacts and adult casual contacts of index cases; BCG, Bacillus Calmette-Guerin; DS, drug susceptible; MDR, multi-drug resistant; TB, tuberculosis; XDR, extensively drug-resistant

Shorter treatment regimens for MDR-TB incorporated both modified shorter treatment regimens (mSTR, 9-month duration) and all-oral shorter treatment regimens utilizing BPaLM (6-month duration).

SCOPE OF ANALYSIS

Study partners identified a range of scenarios for inclusion in the analysis based on national priorities, policy questions and available data (Table 2). Each scenario assumes that changes in intervention coverage occur in 2024 and are sustained until 2030.

Table 2. Scenarios included in the Optima TB Tajikistan analysis, 2023

Scenario	Description
Baseline scenario	Continued spending and fixed allocation of US$ 27.3 million (100% of TB prevention, screening and treatment spending) maintained over 2024-2030
Optimized spending 100%	Continued spending of US$27.3 million (100%) with allocation optimized to reduce DR-TB incidence and TB-related deaths by 2030.
Reduced/increased spending (75%, 125%, 150%) optimized	Considers if available resources for TB programs were reduced or increased. Percentages are relative to the most recent targeted TB spending. Allocations are optimized to reduce DR-TB incidence and TB-related deaths by 2030.
Reaching End TB target milestones by 2030	Assesses the projected progress to reach End TB milestones for 80% reduction in TB incidence and 90% reduction in TB-related deaths from 2015 to 2030.

MODELLING SPECIFICATIONS

Model inputs

A new Optima TB model for Tajikistan was developed for this analysis. Epidemiological, program and cost data (Table 3) were collated by the study team and collaborators using an adapted Excel-based Optima TB data entry spreadsheet. Other model inputs and parameters are described in Appendix B.

Table 3. Main sources of data used in the Optima TB Tajikistan model, 2023

Data type	Source
Epidemiologic data	Demographic data for population size, birth rate estimates and all-cause mortality from UN population division (8); UNAIDS Spectrum estimates for PLHIV (9); Prisoner population estimates from World Prison Brief (10); migrant worker population estimate from Asian Development Bank (7). TB notifications and TB-related deaths supplied by National TB Program, 2015-2022. Assumed proportional drug-resistance among migrants to be the same as 15-64, and among PLHIV not on ART to be the same as prisoners. Historical notifications based on WHO-reported data assuming population disaggregation based on distribution in 2015 (1).
Program coverage data	Treatment initiations and outcomes for MDR and XDR-TB supplied by National TB Program, 2015-2022. Treatment initiation and outcomes for DS-TB based on WHO-reported data assuming population disaggregation for number initiated based on distribution of notifications (1). Number of BCG vaccinations and TPT/LTBI treatment initiations supplied by National TB Program, 2015-2022. Number of people screened by modality provided by National TB Program.
Cost data	Annual cost per treatment initiation provided by National TB Program, 2022, based on weighted cost of included treatment regimens. Costs incorporate treatment drugs, inpatient and outpatient care, treatment observation, laboratory monitoring, adverse event management and psychosocial support. Diagnostic costs provided by National TB Program, 2022. Assumptions regarding diagnostic testing and positive yield by modality informed by literature and program data (11-13) to infer cost per person diagnosed (see Appendix D1).

Model calibration

In consultation with national TB experts, Optima TB was calibrated to available epidemiologic data on TB case notifications and WHO estimated TB incidence (Global TB Programme 2023 estimates). The model was calibrated to closely match estimates of key TB indicators such as active-TB incidence and prevalence and latent TB prevalence. Parameters with high levels of uncertainty, such as force of infection were adjusted to closely match indicators including TB incidence and prevalence (Appendix C).

Optimization objectives

Allocations were optimized to evenly prioritize progress by 2030 on proportionally reducing each of the prevalence of DS-TB, MDR-TB and XDR-TB and reducing the number of TB-related deaths. Based on the estimated baseline conditions of 2022, this resulted in model weightings of 1, 6, and

73 for reductions in the active number of DS-TB, MDR-TB, and XDR-TB cases respectively, and 11 per TB-related death averted.

Optimization constraints

Changes in funding to achieve optimized allocations did not consider reallocation of care costs between hospitalized and ambulatory treatment modalities. Spending was constrained to not reduce current coverage of BCG vaccination and preventive therapy for people living with HIV.

3 Findings

EPIDEMIOLOGICAL SITUATION

TB incidence

In 2022, there were an estimated 8,026 incident TB cases modelled in Optima, including both new and relapse cases and extrapulmonary TB (Table 4). Of these, an estimated 48% were extrapulmonary. Consistent with WHO-reported trends, Optima-estimated TB incidence in Tajikistan has overall significantly declined since the mid-2000s, reaching 80 per 100,000 population in 2022.

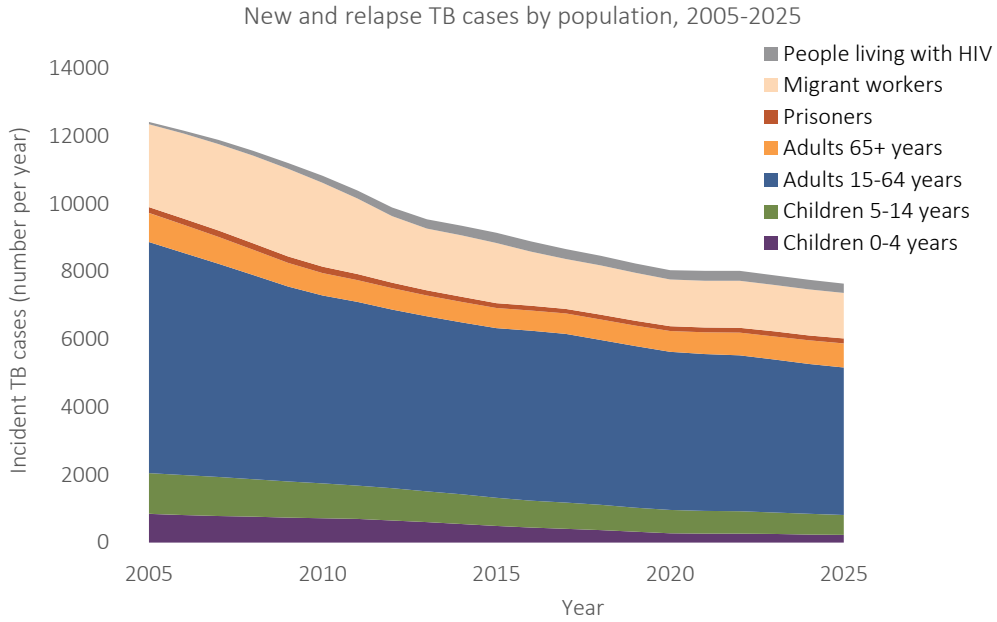
Table 4. Modelled estimated TB incidence, number of prevalent active TB infections, latent infections, and TB-related deaths by sub-population, 2022

	Incident TB			Prevalent TB		
	New and relapse TB cases	Incidence per 100,000 population	Activated DR-TB cases (% of all activated cases)	Total active TB	Latent TB prevalence	TB-related deaths
0-4 years	269	21	47 (17%)	526	1.0%	20
5-14 years	657	28	114 (17%)	1,746	2.9%	84
15-64 years	4,605	82	605 (13%)	6,630	15.0%	519
65+ years	665	186	74 (11%)	1,458	20.1%	84
Prisoners	149	1,237	48 (32%)	144	40.9%	5
Migrant workers	1,386	308	185 (13%)	1,957	32.9%	162
PLHIV	295	2,237	77 (26%)	240	14.6%	82
Total	**8,026**	**80**	**1150 (14%)**	**12,700**	**11.5%**	**958**

Notes: DR, drug-resistant; PLHIV, people living with HIV; TB, tuberculosis.
Source: Optima TB Tajikistan model output, 2023

The majority of new and relapse cases of TB continue to be among adults aged 15-64, with estimated 4,605 incident cases in 2022 (Figure 1). However, relative to population size people living with HIV have the highest incidence of TB in Tajikistan, with estimated 2,237 new and relapse cases per 100,000 population in 2022, concentrated among individuals who are not diagnosed and not on ART. In 2022, an estimated 14% of new and relapse TB infections were DR-TB.

Figure 1. New and relapse TB cases by population group, 2005–2025

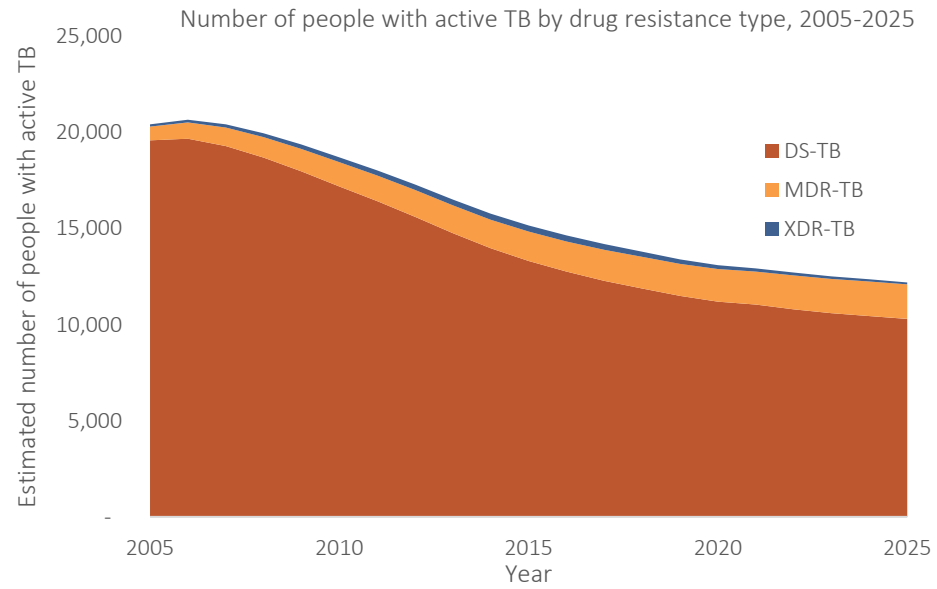


Source: Optima TB Tajikistan model output, 2023.

Prevalent TB

In 2022, there were a cumulative of 12,700 active TB cases in Tajikistan based on Optima modelled estimates, and which approximate half were among those aged 18-64. The estimated prevalence of latent TB was 11.5% and highest among prisoners and migrant workers (Table 4). Among prevalent TB cases in 2022, an estimated 14% of cases were DR-TB. Drug resistance has overall increased over time, but the contribution of XDR-TB cases is decreasing (Figure 2).

Figure 2. Trends in the estimated number of people with active TB by drug resistance type, 2005–2025



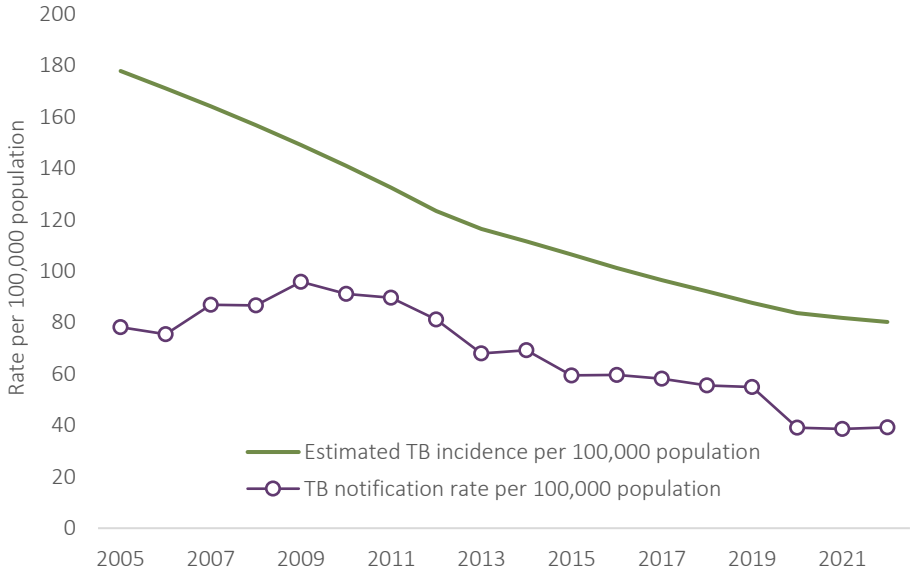
Source: Optima TB Tajikistan model output, 2023.
Notes: DS, drug susceptible; TB, tuberculosis; MDR, multi-drug resistant; XDR, extensively drug resistant.

TB notification and case detection

In 2022, the National TB Protection Program of Tajikistan reported a total of 3,924 TB notifications in Tajikistan (39 per 100,000 population). The estimated case detection rate (the proportion of estimated new and relapse TB cases that are detected in a given year (14)) ranged from 25%-26% among children 0-14 to 66% among adults 65+. Among people living with HIV, the case detection rate was estimated to be 24% prior to initiating ART, but there was rapid TB diagnosis and treatment initiation for those on ART (more than 7 times as many TB notifications as incident cases).

Due to improvements in screening and diagnostics, the notification rate significantly increased from 2005 to 2010, but still remains consistently below estimated TB incidence, indicating a gap in case detection. The decline in notifications from 2020 further widened the gap in case detection, which may have been due to COVID-19-related disruptions and impacts, including decreased screening activities and delays in care-seeking (Figure 3).

Figure 3. Estimated TB incidence rate and notification rate per 100,000 population, 2005–2022



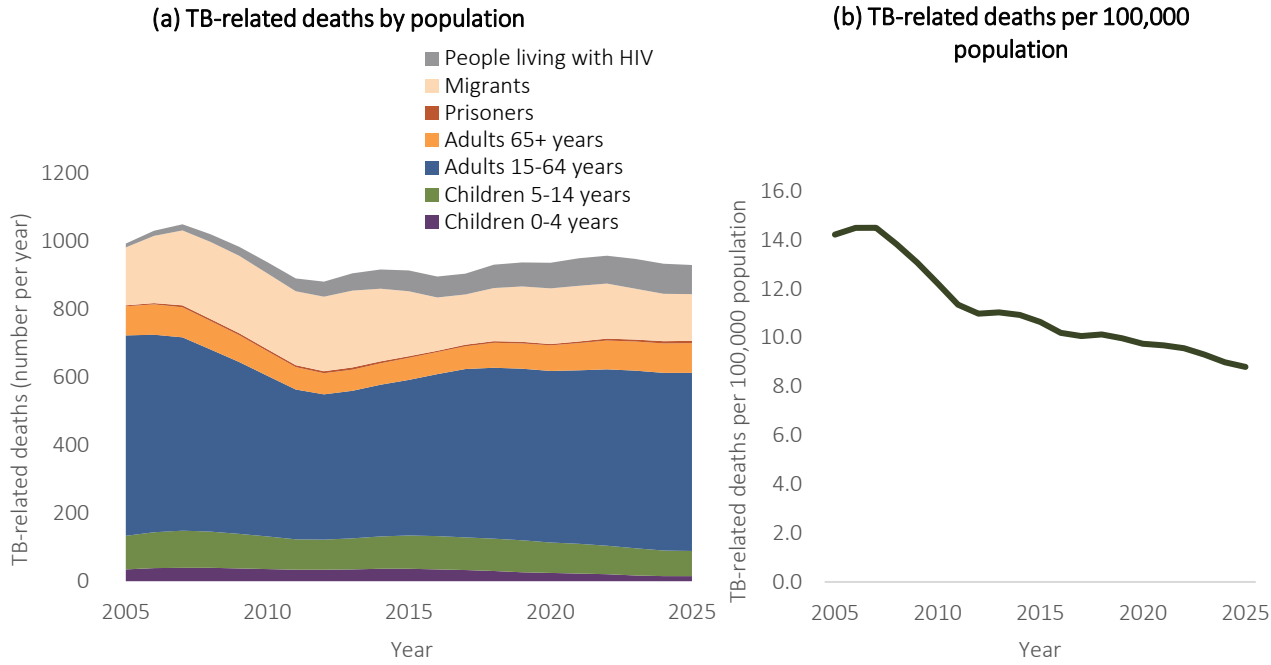
Source: Optima TB Tajikistan model output, 2023. Notification data from WHO Global TB Programme data (2005-2014) and National TB Program (2015-2022).

TB mortality

Overall absolute number TB-related deaths have remained relative stable in Tajikistan, with an average 940 deaths per year based on Optima modelled estimates (Figure 4a). However, given increasing population size, estimated TB-related deaths per 100,000 population have declined from 14.2 per 100,000 in 2005 to 9.6 per 100,000 in 2022 (Figure 4b).

Figure 4. TB-related mortality estimates, 2005–2025

Panel includes: (a) Number of TB-related deaths by population, and (b) Total Tb-related deaths per 100,000 population.

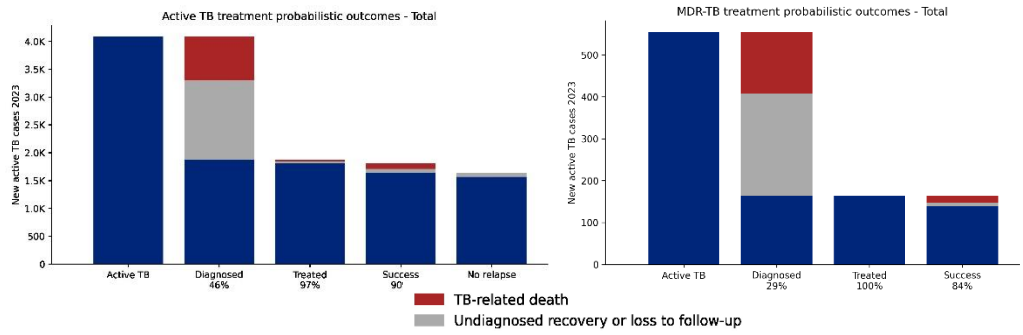


Source: Optima TB Tajikistan model output, 2023.

TB cascade

A probabilistic cascade is reported representing the estimated long-term outcomes of the cohort of people progressing to active TB in 2023. Based on the most recent estimated diagnosis and treatment rates derived from the 2022 data, 46% of all people progressing to active TB in Tajikistan in 2023 would be projected to be diagnosed prior to natural outcome (recovery or death). Of those diagnosed, 97% are projected to be treated (Figure 5).

Figure 5. The projected final cohort outcomes for people progressing to active TB (left) and MDR-TB (right) in 2023 in the status quo scenario



Source: Optima TB Tajikistan model output, 2023.

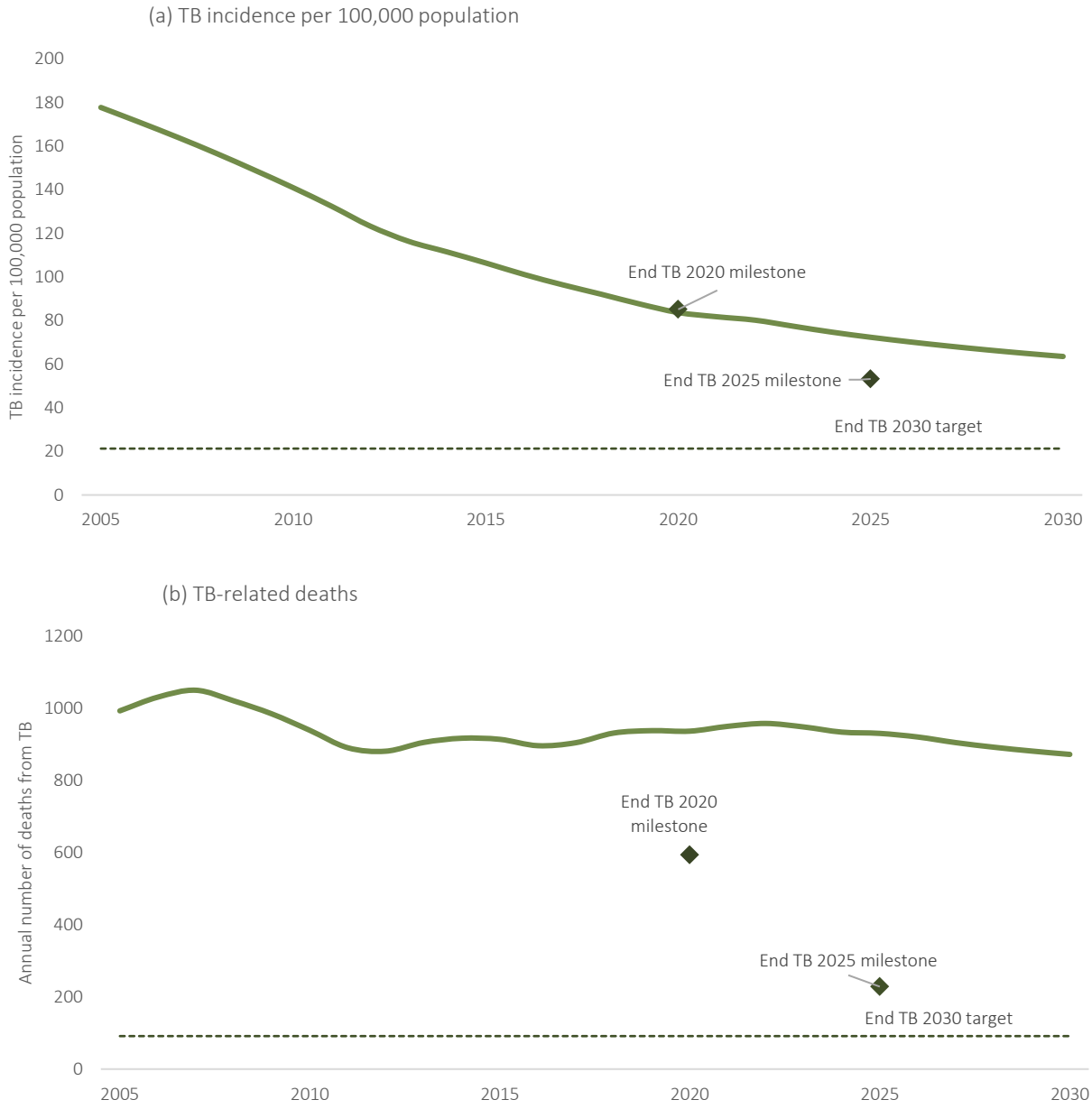
Overall, the probability of treatment success was 90% and slightly lower (84%) for MDR-TB. For both MDR-TB and XDR-TB, NTP-reported treatment failure rates have reduced substantially since 2016, from 10% to 0% among adults aged 15-64.

Progress towards TB targets

Ambitious targets set by the global End TB strategy aim to reach a 80% reduction in incidence rate and 90% reduction in TB deaths by 2030 relative to 2015 (15). To evaluate progress towards the

2030 targets, the strategy defines country milestones for 2020 and 2025. Based on Optima TB modeled projections, Tajikistan achieved the 2020 milestones for TB incidence but not for TB-related deaths. However, is not predicted the reach the End TB 2025 milestones nor 2030 targets with current conditions continued for neither parameter (Figure 6).

Figure 6. Optima TB estimated trends in (a) TB incidence rate and (b) TB mortality in relation to End TB targets



Source: Optima TB Tajikistan model, 2023. End TB milestones (diamond markers) and 2030 targets (dashed line) defined as percentage reduction from 2015 (16). Baseline based on Optima modelled values.

CURRENT TB SPENDING

Based on most recent spending estimates, in 2022 an estimated US$27.3 million was spent on direct TB prevention, screening and treatment programs. Of this, the majority was spent on testing (63%), primarily through contact tracing. Use of shorter, all-oral treatment regimens for DR-TB is increasing in Tajikistan, accounting for 31% of DR-TB treatment initiations in 2022.

WHAT IS THE OPTIMIZED ALLOCATION OF THE TB BUDGET?

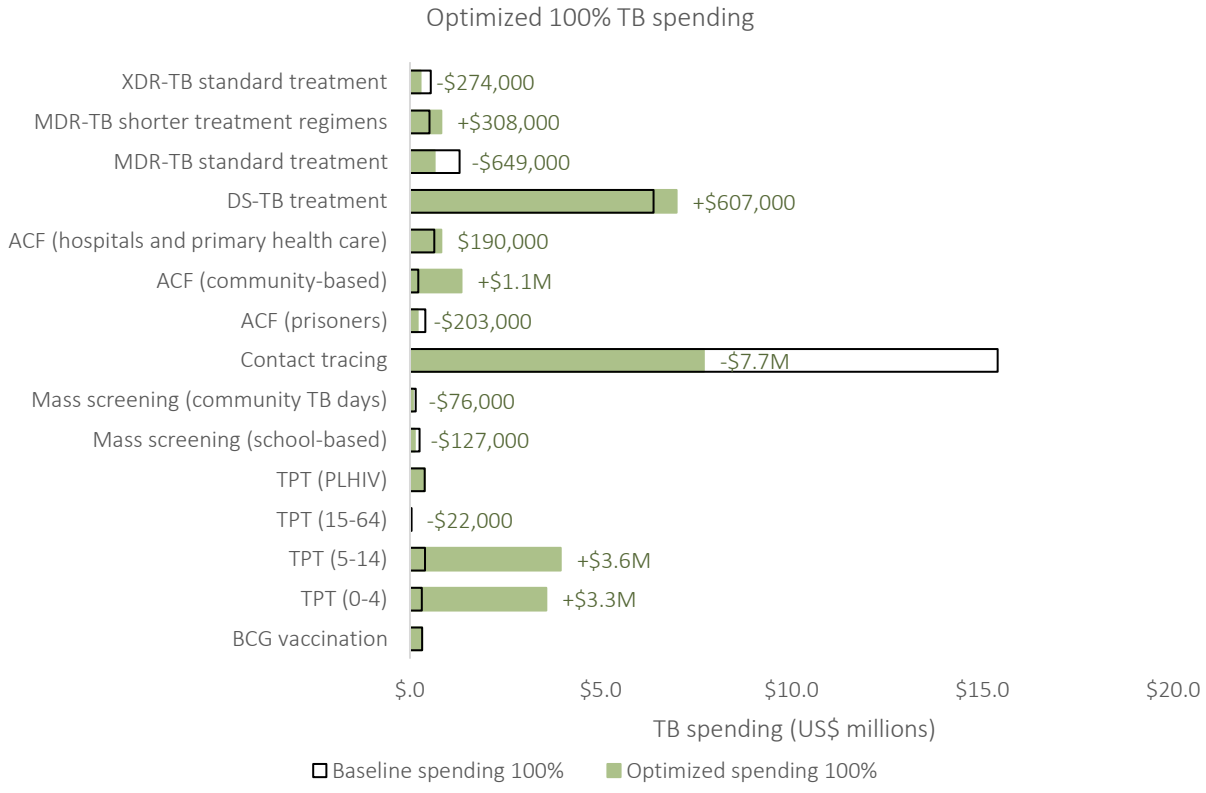
Optimized allocation of TB spending

With 100% of baseline spending maintained, the optimized allocation of the TB budget prioritizes short-course MDR treatment (+US$ 308,000) rather than the standard course MDR treatment (-US$ 649,000) to minimize prevalence of drug-resistant TB by 2030 (Figure 7). Due to the projected decrease in XDR-TB incidence, there is a projected reduction in spending needed for XDR-TB (-$US 274,000) by 2024.

TB preventative therapy is prioritized for scale up among children 0-4 (+US$ 3.3M) and 5-14 (+US$ 3.6M) to prevent activation of latent TB.

In terms of screening and testing, the optimization recommends reallocating spending from mass screening (-US$ 204,000 total) to prioritize more targeted active case finding among individuals at higher risk through community-based active case finding (+US$ 1.1M) and hospitals and primary health care (+US$ 190,000). Contact tracing is deprioritized (-US$ 7.7M) due to the very high unit cost relative to other modalities. Contact tracing has a higher estimated yield and lower cost per person diagnosed among child contacts (0.59% and $9,031 respectively) than adult contacts (0.08% and $62,197 respectively), thus it is more cost-effective to focus contact tracing among children in tandem with TB preventative therapy. Active case finding among prisoners is slightly lower priority in terms of overall epidemic impact, but given the potential for rising deaths in prisons, it is likely important to maintain funding for this program as an equity consideration and to avoid further transmission.

Figure 7. Baseline and optimized allocation of current TB spending for TB prevention, testing and treatment interventions

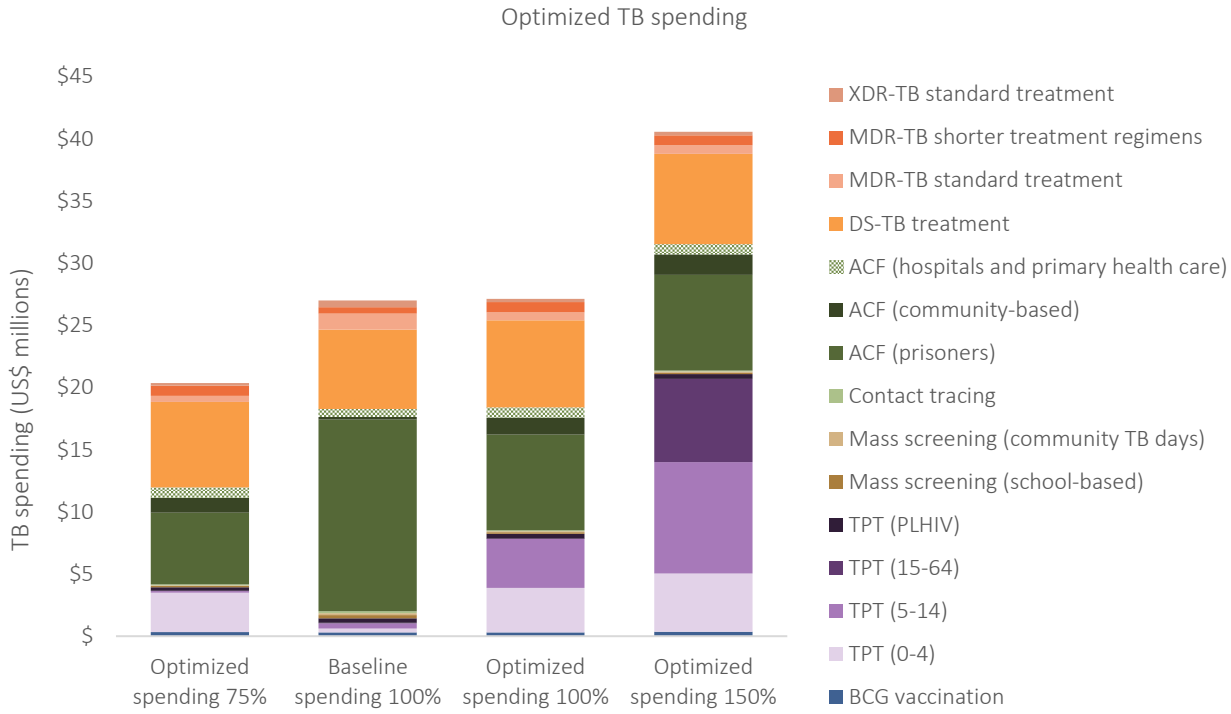


Notes: BCG, Bacillus Calmette-Guérin; DS, drug susceptible; MDR, multi-drug resistant; PLHIV, people living with HIV; TB, tuberculosis; TPT, TB preventive treatment; XDR, extensively drug-resistant.
Source: Optima TB Tajikistan model, 2023

As a result of the shorter course treatment and savings made through more targeted and cost-efficient case-finding, an additional 343 (+33%) people could be initiated on DR-TB treatment from 2024 to 2030. The number of people covered by each intervention can be found in Appendix E.

At lower budget levels below 100%, epidemic gains can be maximized by first maintaining treatment for DS, MDR and XDR-TB based on need utilizing shorter-treatment regimens, and secondly, scaling up contact tracing and TPT for children 0-4 and active case finding through community/mobile screening. With more resources for TB available, TPT is prioritized for expansion first among children 5-14 and then adults 15-64. Detailed spending by budget level can be found in Appendix E.

Figure 8. Recommended allocation of funding by program to minimize drug-resistant TB for varying budget levels (75% to 150%)



Notes: BCG, Bacillus Calmette-Guérin; DS, drug susceptible; MDR, multi-drug resistant; PLHIV, people living with HIV; TB, tuberculosis; TPT, TB preventive treatment; XDR, extensively drug-resistant.
Source: Optima TB Tajikistan model, 2023

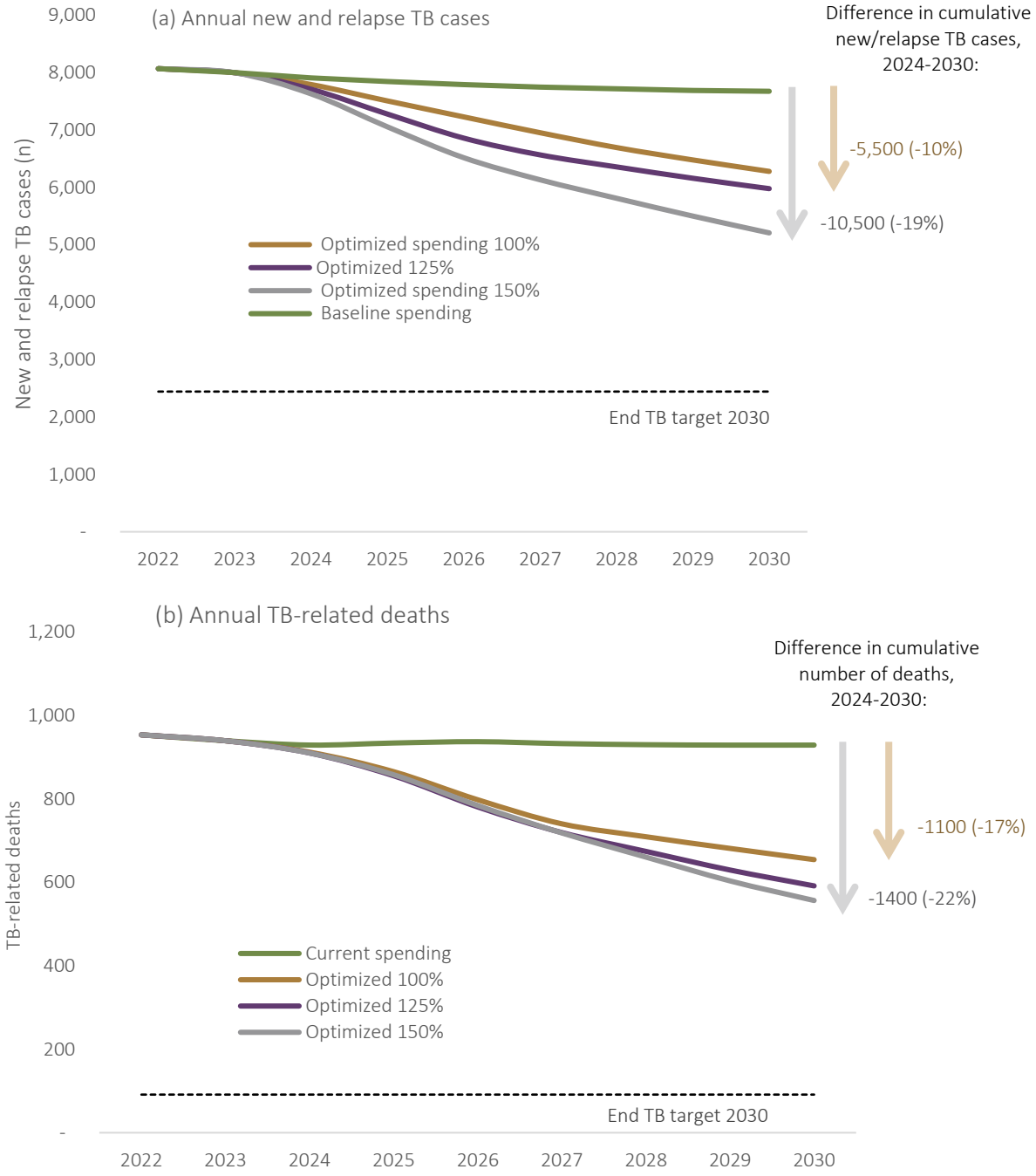
Projected impact of optimized TB spending

With current conditions and spending maintained, Optima TB projects that there would be approximately 51,300 incident TB cases and 6,500 TB-related deaths from 2024 to 2030.

With 100% of baseline TB spending optimized, it is estimated that approximately 5,500 (-10%) new and relapse TB infections and 1,100 (-17%) TB-related deaths could be averted from 2024 to 2030 compared with if baseline spending were continued (Figure 9).

At higher budget levels, incidence is projected to further reduce due to scale-up of TB preventive treatment, with a 19% reduction in new and relapse TB cases and 22% reduction in TB-related deaths compared with baseline spending.

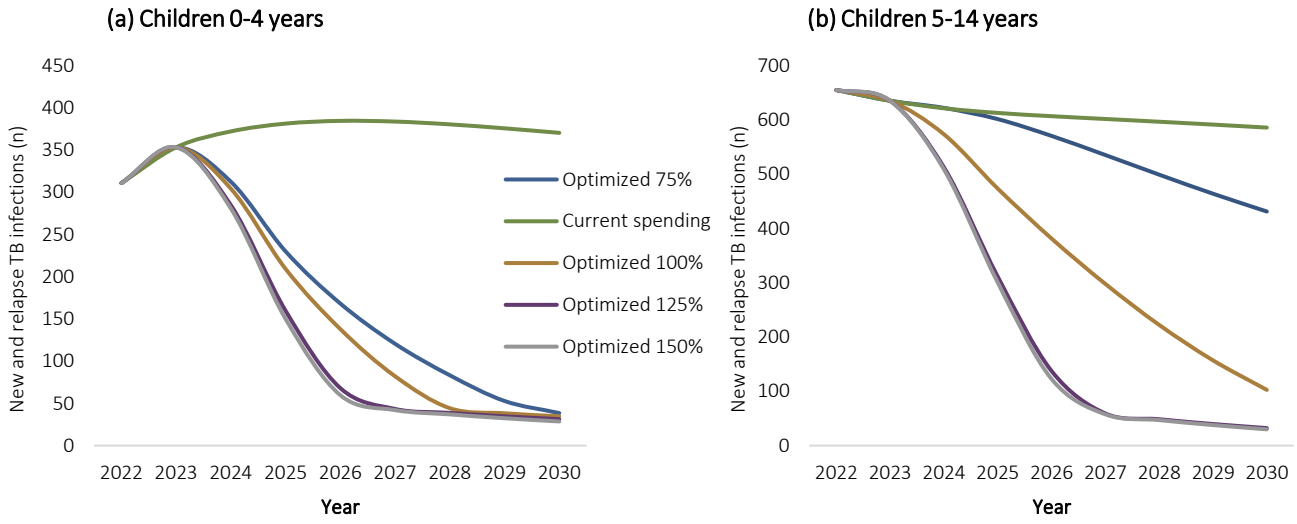
Figure 9. Optima TB projected impact of optimization at varying budget levels on (a) TB incidence and (b) TB-related deaths per 100,000, 2022–2030



Source: Optima TB Tajikistan model, 2023

Projected epidemic impact of optimized spending is particularly high among children given the prioritization of TB preventive treatment among children. With 100% spending optimized, is may be possible to reduce cumulative new and relapse TB cases by 68% among children 0-4 and 48% among children 5-14 compared with if baseline spending were continued (Figure 10).

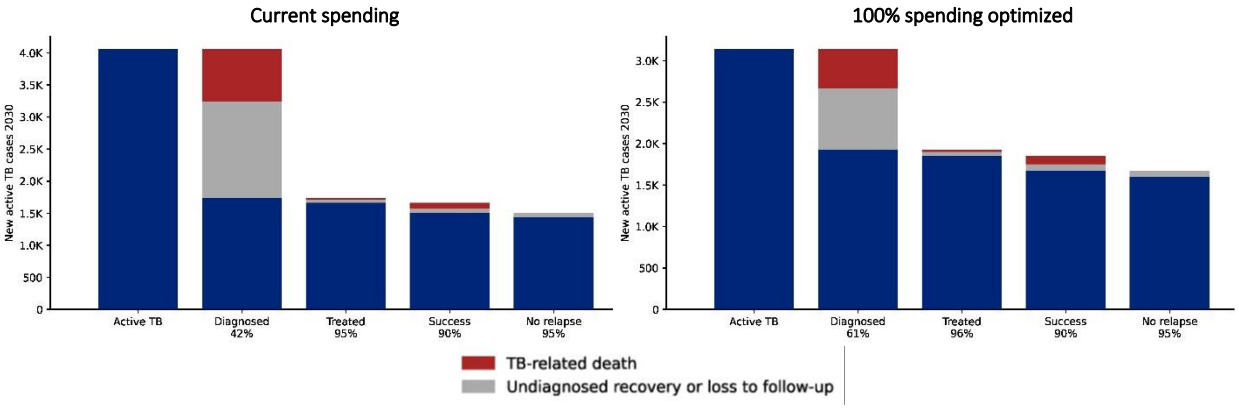
Figure 10. Optima TB projected impact of optimization at varying budget levels on new and relapse TB infections among (a) children 0-4 and (b) children 5-14, 2022–2030



Source: Optima TB Tajikistan model, 2023

By 2030, 100% spending optimized could improve TB diagnosis by +19 percentage points and treatment coverage by +6 percentage points compared to if current spending is continued (Figure 11). This analysis did not consider treatment success to change as a result of shorter treatment regimens, therefore no impact is seen there.

Figure 11. Active TB probabilistic cascade in current spending (left) and 100% optimized spending (right) in 2030



Source: Optima TB Tajikistan model, 2023

WHAT COMBINATION OF INTERVENTIONS WILL MAKE IT FEASIBLE TO ACHIEVE END TB TARGETS BY 2030?

Reaching the End TB 2030 targets is projected to be out of reach with the current set of interventions in Tajikistan with 150% spending. Extremely high budgets that extend TB preventive treatment among adults and mass screening may have the potential to reach End TB targets but are not cost effective. Means to improve the targeting of existing screening strategies, such as extending the involvement of non-governmental organizations and civil society organization to

more effectively reach TB-affected communities, may improve diagnosis rates and increase cost-effectiveness.

4 Study limitations

As with any mathematical modelling analysis it is necessary to make assumptions about data that are not routinely collected or available, and about some of the expected relationships between variables. These assumptions necessarily imply certain limitations:

Epidemic data: Data gaps in reporting of TB notifications by population group and strain required some assumptions which are subject to uncertainty.

TB expenditure and program definitions: Unit costs for interventions were based on scarce data are subject to some levels of uncertainty. Number tested for presumptive TB following x-ray screening and positive yield were informed through national literature (Appendix D1), but may not accurately represent the current program situation in Tajikistan. Diagnostic spending only accounts for commodity costs. There were insufficient cost data to consider the resource required to reach the End TB targets.

The size and profile of the TB epidemic in Tajikistan was aligned with the 2023 WHO Global TB Programme modelled estimates (1). If these estimates are revised in future years subject to emerging data, Optima TB estimates would need to be considered in context of the new estimates.

Prevalence of extrapulmonary TB remains high in Tajikistan, estimated at 48% of new and relapse cases in 2022. The Optima TB model does not currently explicitly model extrapulmonary TB, but factors in a constant proportion of extrapulmonary TB into total costs needed for treatment. The potential for increased diagnosis of extrapulmonary TB, for example as a result of improved case-finding for subclinical TB, is not factored into this analysis.

Resource needs for treatment of drug resistant strains were projected based on the proportion of incident drug resistant cases in 2022, but this may continue to evolve based on either suitability of new drugs to treat previously extensively drug resistant cases as per the WHO reclassification of XDR in 2021 (17), or further emergence of new drug resistance in Tajikistan.

Implementation efficiency: Detailed modelling of implementation efficiency was beyond the scope of the study, and this analysis only included considerations of implementation efficiency in a limited way. Decentralized and ambulatory treatment, ultraportable computer-aided detection (CAD)-enhanced chest X-ray, and engaging civil society organizations in TB screening have been identified as potential ways to improve implementation efficiency in Eastern Europe and Central Asia. However, there were insufficient data to model the additional cost and impact of these potential or planned changes.

Intervention effectiveness: Allocative efficiency modelling depends critically on the availability of evidence-based parameters for the effectiveness of individual interventions. Although these estimates were derived from global systematic literature reviews where possible, they may vary in specific countries and populations. In particular, the quality of implementation and levels of adherence may vary by context and population. All interventions and spending categories for which effectiveness parameters could not be obtained were treated as fixed spending in the mathematical optimization. This includes any programs that may indirectly impact the TB epidemic, such as programs that reduce stigma and discrimination of those with TB.

Geographical heterogeneity: This analysis was conducted on a national level and does not consider sub-national differences in population distribution, epidemiology, or program response.

Non-TB benefits: Effects outside of TB indicators, such as the non-TB benefits of different TB treatment modalities, are not considered in these analyses. Given the range and complexity of interactions among interventions and their non-TB benefits, the model did not consider wider health, social, human rights, ethical, legal, employment-related or psychosocial implications; but acknowledges that they are important aspects to be considered in planning and evaluating TB responses.

Key areas to strengthen data inputs and model certainty may include: triangulation of program costs through top-down spending estimates; standardized case-based recording and reporting to improve performance tracking on contact tracing and TPT; and evidence of program effectiveness.

5 Conclusions

This allocative efficiency analysis for TB prevention and treatment in Tajikistan highlights the necessity to invest in short-duration treatment regimens for drug-resistant TB, TB preventive treatment for children, and more targeted testing strategies.

KEY RECOMMENDATIONS

1. Expanding TB preventive treatment for children 0-14 is a top priority to reduce incidence of TB.
2. Cost-effectiveness of contact tracing could be improved by focusing on screening household contacts over contacts from other settings and prioritizing screening of child contacts.
3. Expanding community-based active case finding is cost-effective and is recommended to reach populations with higher risk of TB infection.
4. Shorter, all-oral regimens for treating drug resistant TB are more cost-effective, allowing for a larger number of people to be treated for the same amount of spending, as well as having fewer side-effects and better adherence for people with TB.

KEY FINDINGS AND OPPORTUNITIES

- Overall, it is estimated that optimizing current resources could lead to a 17% reduction in project TB-related deaths and 10% reduction in projected new and relapse TB cases over 2024 to 2030 compared with if baseline spending were continued.
- Implementing shorter duration treatment for drug resistant TB, including all-oral regimens, can reduce the cost of individual treatment by 39% for MDR-TB, enabling more people to be treated without increasing overall resources. As a result of the shorter course treatment and savings made through more targeted and cost-efficient case-finding, an additional 343 (+33%) people could be initiated on treatment for DR-TB from 2024 to 2030 for the same amount of overall TB spending and 879 (-11%) new/relapse DR-TB cases could be averted over the same period.
- In 2022, 60% of all TB patients were hospitalized in Tajikistan (1). While not assessed in this analysis, additional savings in treatment may be possible by shifting from hospital-based to ambulatory treatment for TB in Tajikistan (18). However, adaptations to health financing structures and mechanisms to transfer savings from hospitals to outpatient care may be necessary to operationalize these changes (19).
- Expanding TB preventive treatment for children 0-14 is a high priority and particularly impactful for reducing childhood TB incidence. The recommended prioritization of TB preventive treatment could avert 1,700 (-68%) of projected cumulative new and relapse cases from 2024 to 2030 among children 0-4, and 2,000 (-48%) among children 5-14 compared with if baseline spending were continued. The availability of new shorter regimens for TPT (e.g. 3HP, 3HR) may support the scale up of TPT (20).
- Contact tracing is Tajikistan has low yield and is associated with very high costs relative to other screening modalities. The estimated cost per person diagnosed was US$ 54,812 through contact tracing compared to US$ 349 for community-based active case finding. The cost-effectiveness of contact tracing could be improved by focusing on screening household contacts over contacts from other settings, and in particular prioritizing

screening of child contacts who had a higher positive yield (0.59%) than adult contacts (0.08%). Outside of household contacts, it may also be possible to improve the impact of contact tracing by effectively targeting it to those most at risk, including repeated contacts, and strategies to promote effective and early diagnosis of index cases.

- Scaling up community-based active case finding, delivered by NGOs in Tajikistan, is recommended to reach populations at higher-risk of TB infection and who may have barriers to accessing health facilities. These screening programs currently have relatively high yield (1.8%) and involving NGOs and CSOs in the delivery of other screening modalities, such as contact tracing, may also help to improve case finding and cost-effectiveness.
- Integration of HIV and TB services can help to prevent TB infections among people living with HIV, reduce delays in both TB and HIV diagnosis and treatment, reduce loss-to-follow up, and lessen burden for patients (21).
- Expanding active case finding in hospital and primary health care by up to 30% is advised. This is assumed to be feasible based on pre-COVID rates of screening and diagnosis, although care-seeking behavior has not yet increased and additional interventions to increase awareness for TB testing may be necessary to achieve this.
- Mass screening programs have demonstrated extremely low yield and high cost per diagnosis in Tajikistan and are not a priority for expansion where there is any potential to expand other more targeted interventions such as community-based or health facility-based active case finding.
- Tajikistan is not projected to reach the 2030 End TB target for reduction in incidence and TB-related deaths with current programs optimized. Stigma and discrimination of people with TB can be a major barrier to care seeking and treatment success (22). Efforts to adopt people-oriented, family-centered, and predominantly outpatient delivery models, engage with relevant civil society organizations to more effectively reach TB-affected communities, and reducing stigma and discrimination of those with TB may advance progress in reaching End TB targets and improving the health and wellbeing of people with TB.

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7 Appendices

APPENDIX A. OPTIMA TB MODEL OVERVIEW

A.1. Tuberculosis model structure

The Optima TB tool is based on a dynamic, population-based TB model encapsulated within an intervention and costing framework (23). The model uses a linked system of ordinary differential equations to track the movement of people among health states (Figure A1). The overall population is partitioned in two ways: by population group and by TB health state. TB infections occur through the interactions among different populations. Each compartment in Figure A1 corresponds to a single differential equation in the model, and each rate (Figure A1 arrows) corresponds to a single term in that equation. The analysis interprets empirical estimates for model parameter values in Bayesian terms as previous distributions. The model then must be calibrated: finding posterior distributions of the model parameter values so that the model generates accurate estimates of notified TB cases, TB incidence, TB prevalence, the number of people on treatment, and any other epidemiological data that are available (such as TB-related deaths). Model calibration and validation normally should be performed in consultation with governments in the countries, in which the model is being applied.

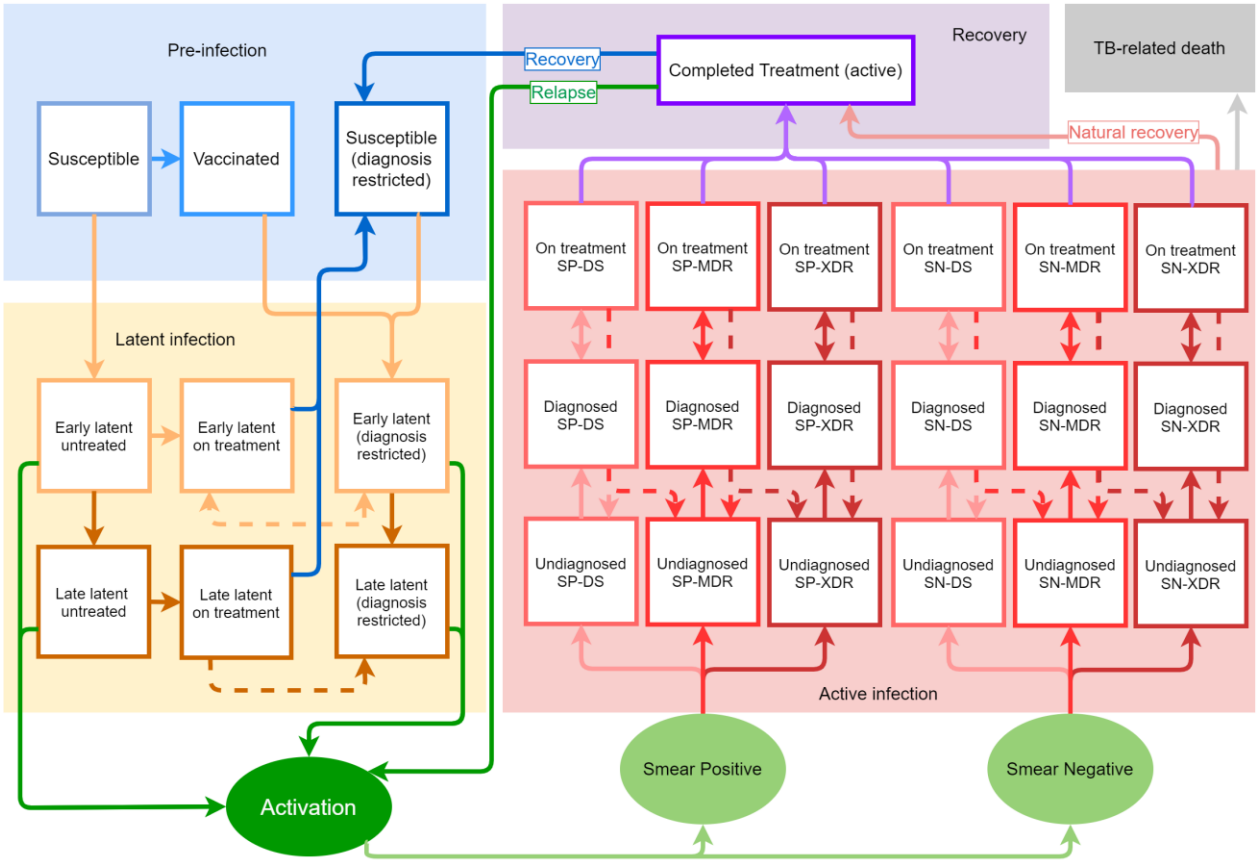
The WHO definition for incident TB cases includes both new and relapse cases. In the model, incident TB cases correspond to the following transitions between compartments (Table A1):

- New cases: these correspond to the number of progressions to active TB from latent-TB compartments, including those who have been re-infected among people who have previously recovered from active TB more than two years previously
- Relapse cases: these correspond to a new episode of TB disease after previous completion of treatment or natural recovery.

Treatment success includes ‘cured’ and ‘treatment completion’, as per the WHO definition:

- Death during TB treatment is not included in treatment failure, but is considered separately
- Treatment failure and ‘loss to follow-up’ during treatment are included as separate outcomes in the model.

Figure A1. Optima TB model diagram



Source: Goscé (2021)
Note: Each compartment represents a single population group with the specified health state. Each arrow represents the movement of numbers of individuals between health states. All compartments except for "susceptible" and "vaccinated" represent individuals with either latent or active TB. Death can occur for any compartment, but TB related mortality varies between compartments. SN-DS = smear negative drug susceptible; SP-DS = Smear-positive drug susceptible; SP-MDR =smear positive-multi-drug resistant; SN-MDR =smear negative-multi-drug resistant; SN-XDR = smear negative-extensively drug-resistant; TB = tuberculosis.

Table A1. Overview of key Optima TB Model features and definitions

TB parameters	Model features and definitions
Disaggregation by smear-status and drug-resistance	DS-TB, MDR-TB, XDR-TB. Not disaggregated by smear status in Optima TB Tajikistan 2023 analysis.
New vs. relapse cases	The WHO definition for incident TB cases includes both new and relapse cases. In the model, incident TB cases correspond to the following transitions between compartments: New cases: these are represented by the number of progressions to active TB from early and late latent-TB compartments. 'New' also includes recurring episodes of TB from the recovered compartment following re-infection Relapse cases: these correspond to a new episode of TB disease after previous completion of treatment or natural recovery.
Latent TB	Multiple compartments for latent TB infection (LTBI) Cannot skip latent state for disease progression States include undiagnosed, on treatment, and completed treatment Accounts for re-infection and latent care-status using a secondary latent TB pathway. Cases previously treated for LTBI, or vaccinated

	individuals, can transition to the active TB pathway in the case of reinfection
Vaccination, immunity and resistance	Vaccination explicitly included in model Patients that spontaneously clear from infection
Treatment	States for undiagnosed, diagnosed, diagnosed but not on-treatment, on-treatment, and recovered patients for different types of drug resistance Failed or defaulted treatment can acquire drug resistance
Treatment outcomes	Treatment success includes 'cured' and 'treatment completion', as per the WHO. Other outcomes of treatment in the model include 'loss to follow-up' during treatment, 'treatment failure', 'treatment failure with escalation of drug resistance', 'death during treatment'. Where data is reported as 'not evaluated' it may be assumed to be allocated proportionally to other compartments or based on other evidence.
Population structure, key populations and People living with HIV	Age-structured populations can be user defined. Ability to specify additional key populations with defined transition rates to/from general population groups. People living with HIV represented as a separate key population disaggregated by HIV treatment status.

A.2. TB Resource Optimization

Optima TB is able to calculate allocations of resources that optimally address one or more TB-related objectives (for example, impact-level targets in a country's TB national strategic plan). Because this model also calculates the coverage levels required to achieve these targets, Optima TB can be used to inform TB strategic planning and the determination of optimal program coverage levels. The key assumptions influencing resource optimization are the relationships among (1) the cost of TB interventions for specific target populations, (2) the resulting coverage levels of targeted populations with these TB programs, and (3) how these coverage levels of TB programs for targeted populations influence screening and treatment outcomes. Such relationships are required to understand how incremental changes in spending (marginal costs) affect TB epidemics. To perform the optimization, Optima uses a global parameter search algorithm, which is an adaptive stochastic descent algorithm (23).

A.3. Uncertainty Analyses

Optima uses a Markov chain Monte Carlo algorithm for performing automatic calibration and for computing uncertainties in the model fit to epidemiological data. With this algorithm, the model is run many times (typically, 1,000–10,000) to generate a range of epidemic projections. Their differences represent uncertainty in the expected epidemiological trajectories. The most important assumptions in the optimization analysis are associated with the cost-coverage and coverage-outcome curves.

APPENDIX B. MODEL INPUTS

B.1. Demographics

Table B1. Demographic inputs for Optima TB Tajikistan model, 2023

Parameter	2022	Source(s) or assumptions
Population size		
0-4	1,269,089	UN Population Division 2022 (8); NTP provided data (prisoners); Asian Development Bank for male migrant workers (7); 2021 estimates for PLHIV (9).
5-14	2,340,744	
15-64	5,509,606	
65+	345,556	
Prisoners	12,000	
Migrant workers	461,757	
PLHIV not on ART	5,103	
PLHIV on ART	7,897	
Percentage of people who age into the next age category per year		
0-4	20%	UN Population Division 2022
5-14	9%	
15-64	1%	
Annual number of births	258,555	UN Population Division 2022
Annual non-TB death rate		All-cause mortality based on UN Population Division 2022 and adjusted during calibration
0-4	0.6%	
5-14	0.0%	
15-64	0.3%	
65+	5.8%	
Prisoners	0.4%	
Migrant workers	0.3%	
PLHIV not on ART	0.3%	
PLHIV on ART	0.3%	
Net number of migrants per year	19,999	UN Population Division 2022. Total number distributed by age-weighting for 5-14, 15-64 and 65+ amongst number of departing emigrants.

ART, antiretroviral therapy; NTP, National TB Protection Program of Tajikistan; PLHIV, people living with HIV; TB, tuberculosis.

B.2. Tuberculosis notifications

Table B2. Number of notified TB infections per population group, 2022

Population group	DS-TB	MDR-TB	XDR-TB	Total notified
0-4	61	15	0	76
5-14	160	14	2	176
15-64	2017	193	4	2,214
65+	420	27	2	449
Prisoners	48	23	1	72
Migrant workers	752	38	1	791
PLHIV not on ART	69	4	0	73
PLHIV on ART	69	4	0	73
Total	3,597	317	10	3,924

Note: ART, antiretroviral therapy; DS, drug susceptible; TB, tuberculosis; MDR, multi-drug resistant; PLHIV, people living with HIV; XDR, extensively drug-resistant.
Source: National TB Protection Program in Tajikistan data, 2023

B.3. Epidemiological parameters

Description	Value	Population	Source or assumption
Vaccinations administered (/year)	106,813 (2022)	0-4	National TP Programme data, 2023
Early Latency Departure Rate	0.2	All populations unless specified	Houben (2016) - appendix of TIME model. 0.1%/year reactivation rate (0.01-0.25)
	0.99	PLHIV not on ART	
Late Latency Departure Rate*	0.0015	0-4, prisoners, PLHIV on ART	Andrews (2012)- risk of progression to active.Andrews (2012)
	0.0005	5-14, 15-64	
	0.0005	65+	Assumed decrease in late latency departure rate over time (values shown for 2018 onwards)
	0.05	PLHIV not on ART	
Probability of Early-Active vs. Early-Late LTBI Progression*	0.19	0-4	Andrews (2012)- risk of progression to active. Assumed probability of progression decreased over time (values shown for 2010 onwards)
	0.17	5-14, prisoners, migrant workers, PLHIV on ART	
	0.12	15-64	
	0.3	65+	
	0.93	PLHIV not on ART	
Infection Vulnerability Factor (Vaccinated vs. Susceptible)	0.5	0-14	Mangtani (2014) (protective efficacy of BCG found to range from 0-80%). A value of 0.5 was used for populations aged 0–14, and no protection (i.e., 1) was used for all populations older than 14 years.
	1.0	15+	
Infection vulnerability factor (relative population susceptibility)	5.6	0-4	A value of '1' is the default, but this is likely to be significantly higher in vulnerable populations such as people living with HIV. Values between 2 and 24 were used in calibrations.
	2	5-14	
	2.16	15-64	
	3.2	65+	
	11	Prisoners	
	5.6	Migrant workers	
	24	PLHIV not on ART	
	3.2	PLHIV on ART	
Smear positive (SP) TB Infectiousness*	1.0	All populations unless specified	A value of '1' is the default
	0.3	0-4	
	0.7	5-14	
Smear negative TB Infectiousness (Compared to SP-TB)	0.22	All populations	Behr (1999)
Duration of active TB until natural outcome (years)	3.5	All populations unless specified	WHO, Tiemersma (2011)
	2.0	PLHIV not on ART	
Untreated-TB death rate	37.4%	All populations unless specified	Informed by WHO, Tiemersma (2011). Time-varying rate used (values shown for 2022 onwards). Calibrated to align with national reported TB mortality rates given an implied ratio of SP to SN.
	18.7%	0-14	
	95%	PLHIV not on ART	
	75%	PLHIV on ART	

Notes: ART, antiretroviral therapy; LTBI, latent TB infection ; PLHIV, people living with HIV; SN, smear-negative; SP, smear-positive; TB, tuberculosis.

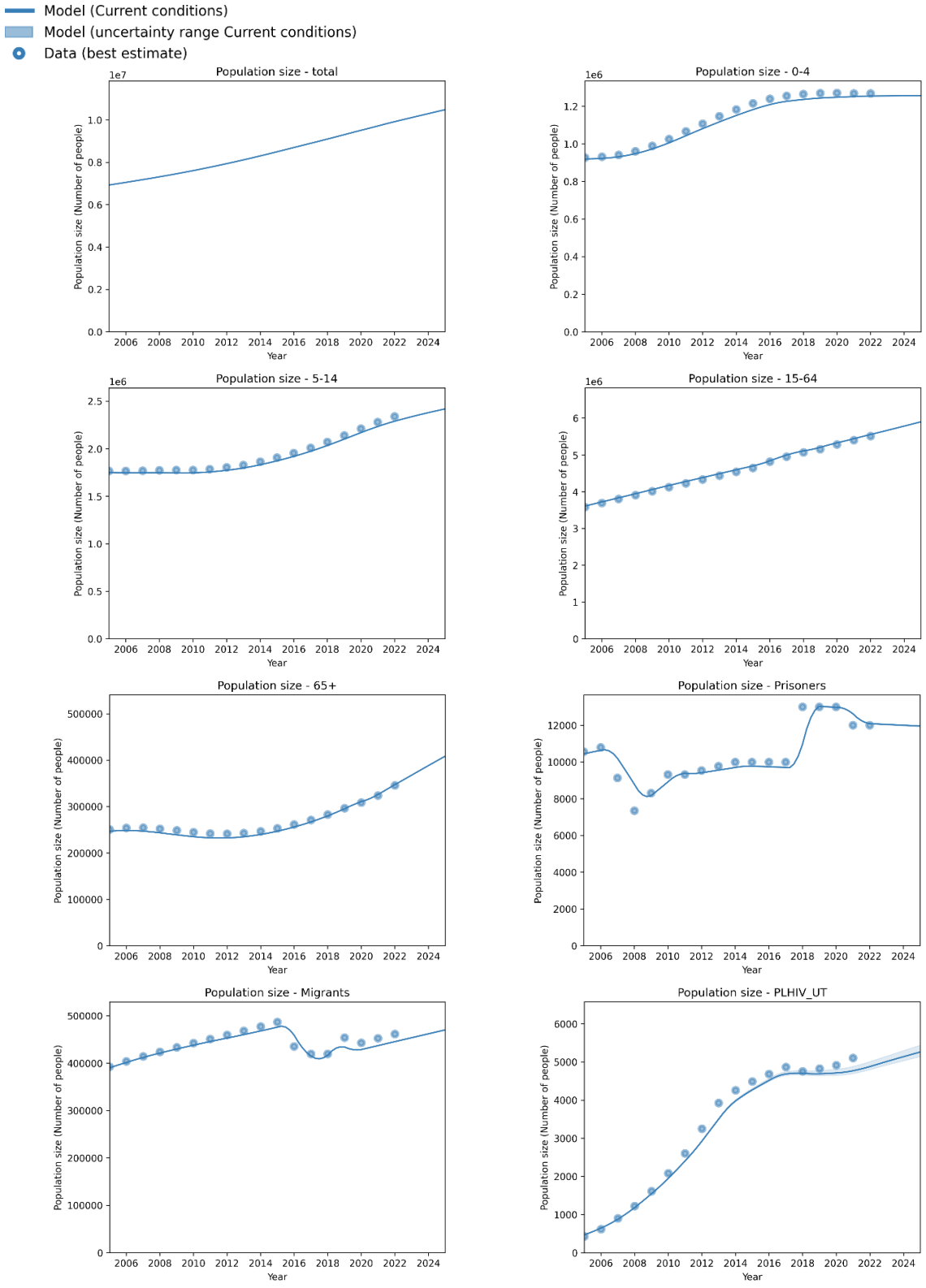
Table B3. Treatment outcomes, 2022

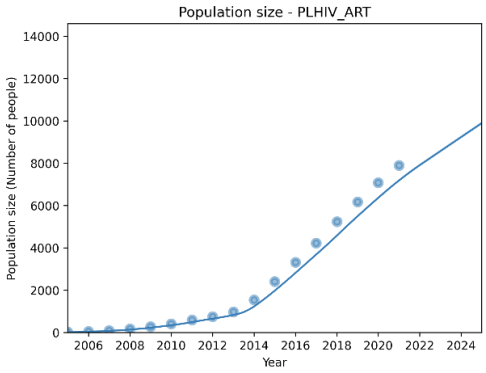
	Average treatment duration (days)			Treatment success[1]			Loss to follow up			Treatment failure (no escalation)			Died		
	DS-TB	MDR-TB	XDR-TB	DS-TB	MDR-TB	XDR-TB	DS-TB	MDR-TB	XDR-TB	DS-TB	MDR-TB	XDR-TB	DS-TB	MDR-TB	XDR-TB
0-4	170	414	250	92%	100%	100%	3%	0%	0%	1%	0%	0%	4%	0%	0%
5-14	170	414	250	92%	94%	94%	3%	0%	0%	1%	0%	0%	4%	6%	6%
15-64	170	414	250	92%	87%	87%	3%	5%	5%	1%	0%	0%	4%	7%	7%
65+	170	414	250	92%	67%	67%	3%	3%	3%	1%	0%	0%	4%	31%	31%
Prisoners	170	414	250	92%	79%	79%	3%	14%	14%	1%	0%	0%	4%	7%	7%
Migrant workers	170	414	250	92%	87%	87%	3%	5%	5%	1%	0%	0%	4%	7%	7%
People living with HIV not on ART	170	414	250	66%	67%	67%	3%	3%	3%	1%	0%	0%	29%	31%	31%
People living with HIV on ART	170	414	250	66%	87%	87%	3%	5%	5%	1%	0%	0%	29%	7%	7%

Note: 1, Treatment success includes individuals who have completed treatment without bacteriological confirmation of cure; DS, drug susceptible; TB, tuberculosis; MDR, multi-drug resistant; XDR, extensively drug-resistant.
Source: National TB Protection Program in Tajikistan, 2023 and WHO TB Programme data, 2023

APPENDIX C. CALIBRATION

C.1. Populations size calibration figures

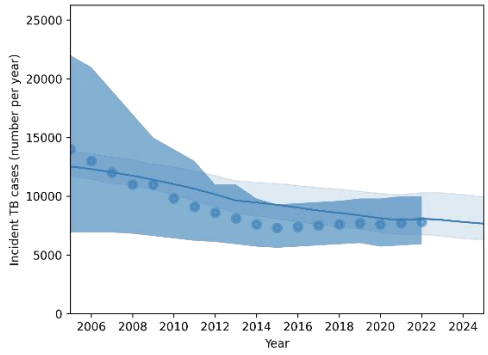




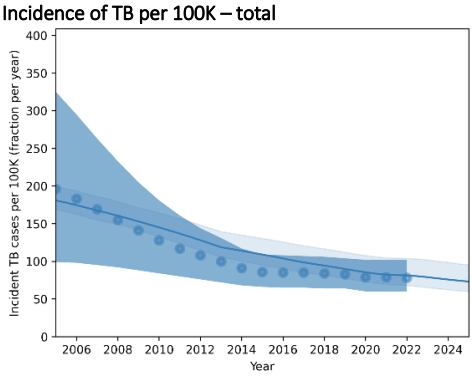
C.2. Selected TB epidemic calibration figures

Model (Current conditions)
Model (uncertainty range Current conditions)
Data (best estimate)

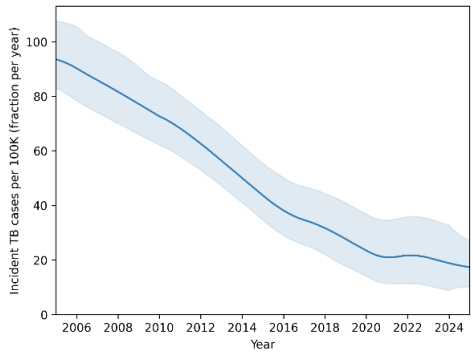
TB Incidence – total cases



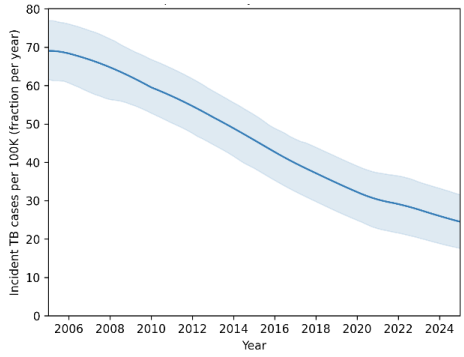
Incidence of TB per 100K – total



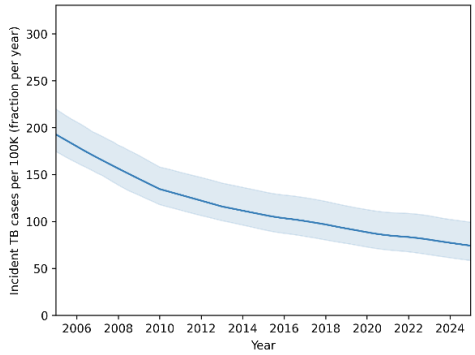
TB incidence – 0-4



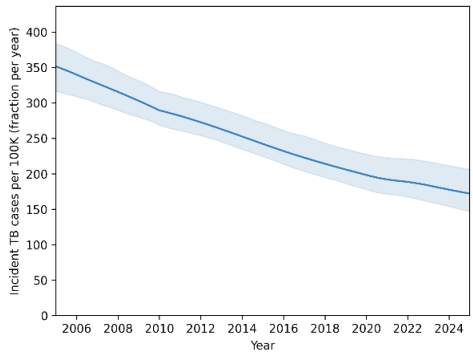
TB incidence – 5-14



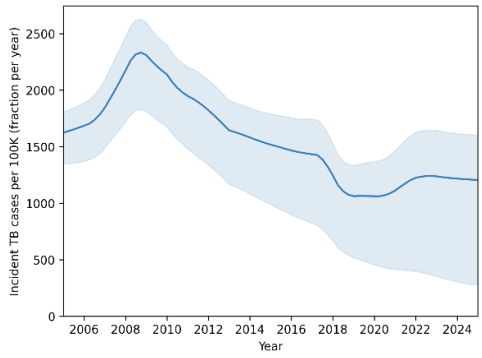
TB incidence – 15-64



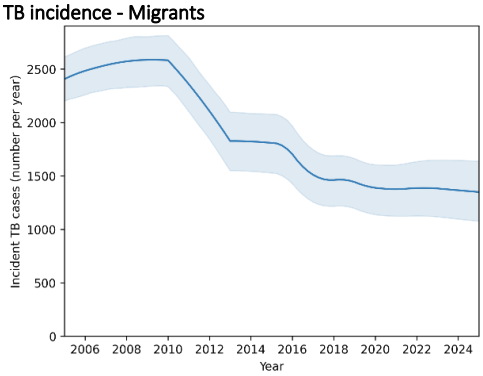
TB incidence – 65+



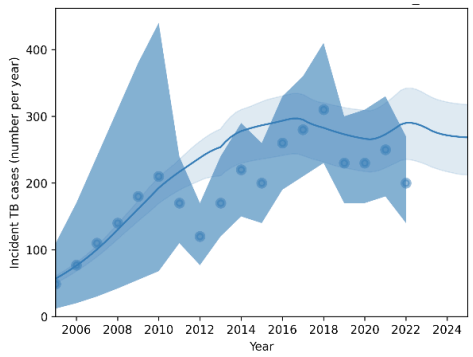
TB incidence – Prisoners



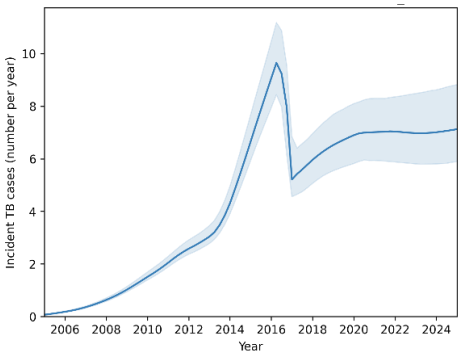
TB incidence - Migrants



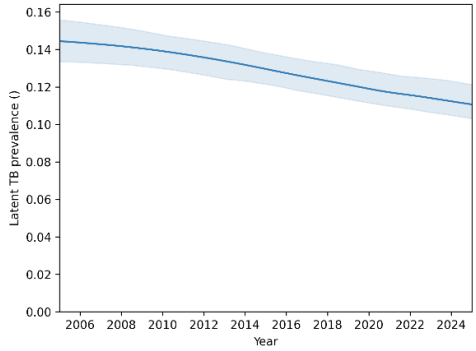
TB incidence – PLHIV not on ART



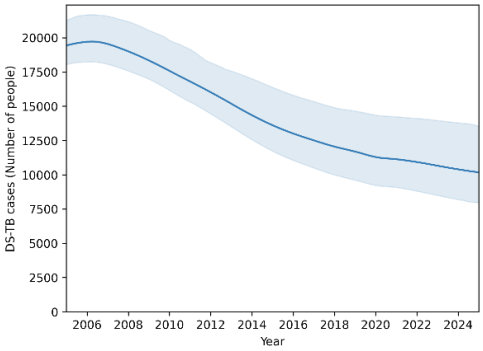
TB indicence – PLHIV on ART



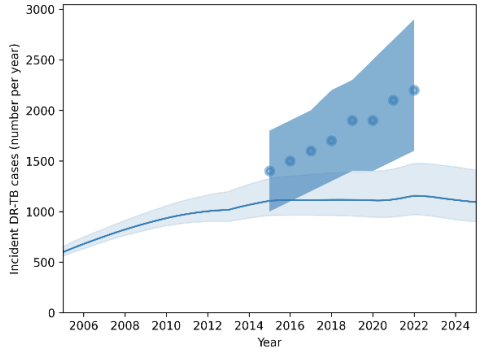
Latent TB prevalence – total



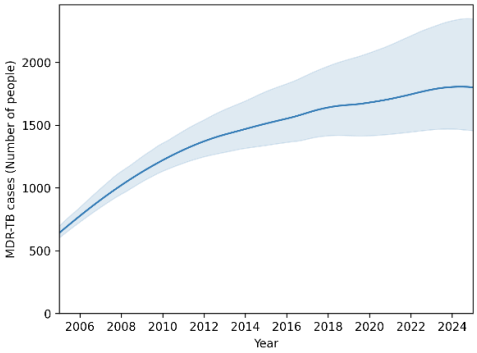
Active DS-TB cases – total



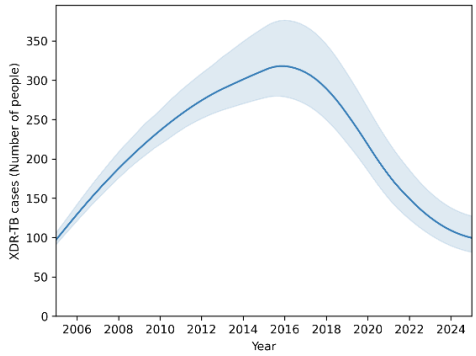
DR-TB incidence – total cases



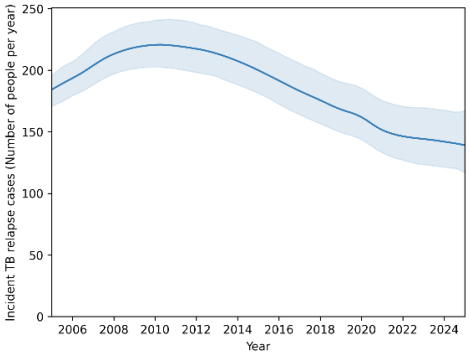
Active MDR-TB cases – total



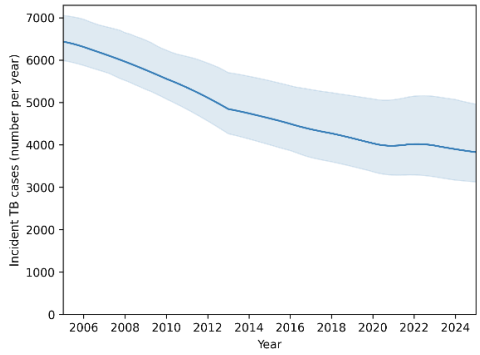
Active XDR-TB cases – total



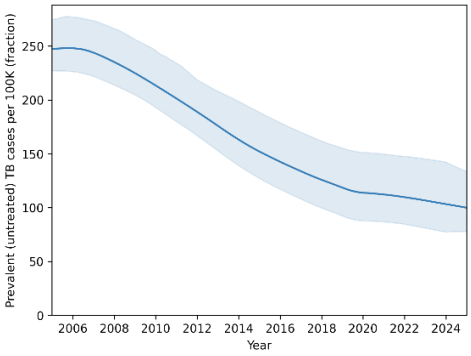
New active relapse pulmonary TB cases – total



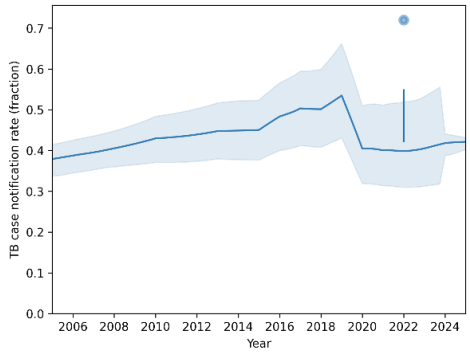
New active pulmonary TB cases – total



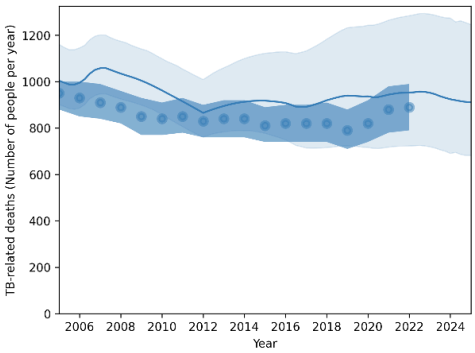
Prevalence of (untreated) pulmonary TB per 100K– total



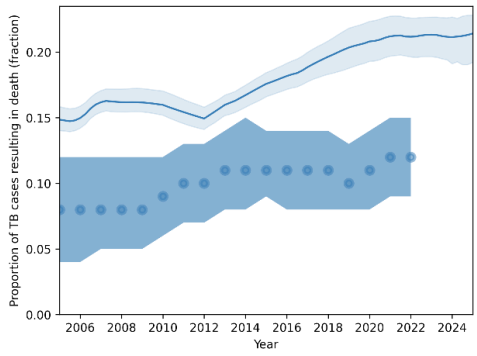
TB cases notification rate– total



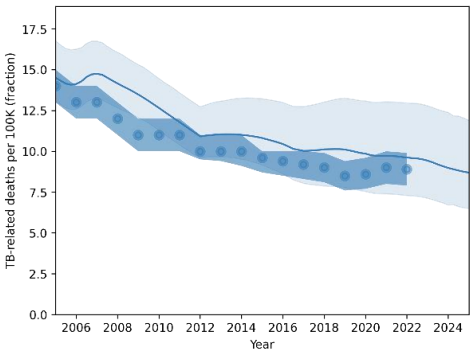
TB-related deaths – total



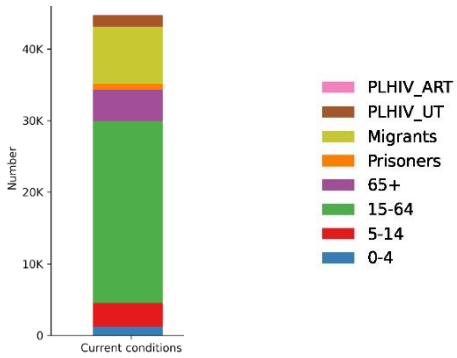
Case fatality ratio – pulmonary TB total



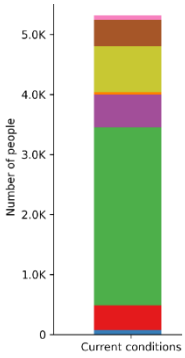
TB-related deaths per 100K – total



Cumulative TB incidence 2018 to 2030



Cumulative TB-related deaths 2018 to 2030



APPENDIX D. PROGRAM DEFINITIONS

D.1. Derivation of testing costs by screening modality

Table D1. Derivation of testing costs by screening modality

Modalities	Initial screening			Diagnostic testing		Yield			Costs (USD)			Assumptions
	Symptom screening (number reached)	X-ray (number reached)	Cost per person screened (USD)	Xpert (number tested)	Average diagnosis costs per person	Number diagnosed	Positive yield among all screened	Share of total positive (%)	Total spending	Cost per person diagnosed	Cost per person screened	
Mass screening (school-based)	unk	5,000	$50.00	250	$18.01	4	0.07%	0%	$254,501	$72,715	$50.90	% with Xpert assumed to be half of overall reported rate (5%). Yield based on Optima TB-estimated TB prevalence (0.07%).
Mass screening (community TB day)	unk	3,000	$50.00	150	$18.01	3	0.10%	0%	$152,701	$50,900	$50.90	Proportion with Xpert assumed to be half of overall reported rate (5%).Yield based on Optima TB-estimated TB prevalence (0.1%)
Active case finding (prisoners)	unk	8,000	$50.00	285	$18.01	72	0.9%	2%	$405,141	$ 5,627	$50.64	Number screened (x-ray) and diagnoses provided by NTP. Assume 3.6% of those with x-ray have presumptive TB and are tested via Xpert based on study data of proportion with radiographic findings (12).
Active case finding (community-based)	33,862	205	$50.00	11,529	$18.01	625	1.8%	16%	$217,837	$349	$6.43	Screening and yield data provided by NTP based on screening implemented through NGOs. Note, cost per person screened based on number with symptom screening (not costed)
Active case finding (hospital and primary health care)[1]	unk		$50.00	35,216	$18.01	2940	8%	75%	$634,094	$216	$18.01	10% yield found in study of ACF in polyclinics, diabetes centre and pre-detention (13). Yield adjusted for plausibility with other modality data and total notifications. Number tested inferred from total number of Xpert tests minus total from other modalities.
Contact tracing (child contacts)	unk	6,564	$50.00	1,346	$18.01	39	0.59%	1%	$352,429	$ 9,031	$53.69	Number screened provided by NTP. % referred for diagnostic testing (20.5%) & positive yield (2.9% for *tested* contacts) based on study of contact tracing among DR-TB cases (11) and used to estimate number Xpert tested and number diagnosed.
Contact tracing (adult contacts)	unk	297,910	$50.00	8,341	$18.01	242	0.08%	6%	$15,045,694	$62,197	$50.50	Number screened provided by NTP. % referred for diagnostic testing 2.8%) & positive yield (2.9% for *tested* contacts) based on study of contact tracing among DR-TB cases (11) and used to estimate number Xpert tested and number diagnosed.
TOTAL		**320,474**		**57,118**		**3,924**						Total numbers provided by NTP.

Notes: 1, Includes some passive case finding; ACF, active case finding; NTP, National TB Protection Program of Tajikistan; unk, unknown.

D.2. Program details

Table D2. Program details and estimated unit costs for TB interventions in Tajikistan

		Unit	Unit cost (USD)	Assumptions
TB PREVENTION PROGRAMS				
BCG vaccination		Cost per infant vaccinated	$1.28	Due to missing data, a regional unit cost is assumed - an average from other Eastern European and Central Asian countries ($1.32, $1.12, $1.39)
TB preventive therapy (TPT) for people living with HIV		Cost per person per year	$3.36	Funded through the HIV program. Constrained not to reduce below current spending.
TPT for household contacts aged:	0-4 years 5-14 years 15-64 years	Cost per person who is a contact of active TB, per preventive therapy initiation	$372 $371 $406	Weighted cost by regimen, including 3HP (rifapentine + isoniazid) and 6H (isoniazid). Adjusted for the estimated prevalence of early latent TB among household contacts by age group (29, 30), the estimated cost per contact with early latent TB was estimated as $1048, $1545, and $3123 for household contacts aged 0-4 years, 5-14 years, and 15+ years respectively.
SCREENING AND DIAGNOSIS PROGRAMS				
Contact tracing		Per person diagnosed	$54,812	Based on average diagnostic costs. Number screened provided by NTP. Assumes a yield of 0.59% among child contacts and 0.08% among adult contacts screened, based on study data of contact tracing among index cases with DR-TB (11). Constraint on maximum expansion of contact tracing based on: expected number of index cases, allowing for an increase in case-finding; average number of contacts per index case in Tajikistan study (11); and estimated TB prevalence among household contacts by age group (29). See also Table D1.
Active case finding (prisoners)		Per person alive per year	$34	Number screened (x-ray) and diagnoses provided by NTP. Assume 3.6% of those with x-ray have presumptive TB and are tested via Xpert based on study data of proportion with radiographic findings (12).
Active case finding (community-based)		Per person diagnosed	$349	Implemented by NGOs, and assumed to reach adults, migrant workers and PLHIV in the model. Yield of 1.8% based on program data. Assumed to be able to reach up 5% of undiagnosed TB cases per year given sufficient funding.
Active case finding (hospital and primary health care)		Per person alive per year	$0.06	May also include some passive case finding. Number tested inferred from total number of Xpert tests minus total from other modalities, and yield informed by a Tajikistan-based study (13).

Mass screening (school-based	Per person screened	$1421	% with Xpert assumed to be half of overall proportion of x-rays with suspicion of TB rate (5%). Yield based on Optima TB-estimated TB prevalence (0.07%). Constrained based on population size of children 5-14.
Mass screening (community TB day)	Per person screened	$50.90	% with Xpert assumed to be half of overall proportion of x-rays with suspicion of TB rate (5%). Yield based on Optima TB-estimated TB prevalence (0.1%).
TB TREATMENT PROGRAM			
DS-TB treatment (standard)	Per person initiating treatment	$1,627	Based on 6-month standard treatment with Ethambutol/isoniazid/pyrazinamide/rifampicin. Incorporates cost of drugs ($49), inpatient costs ($112), outpatient and monitoring costs ($296), treatment observation costs ($350), adverse event management ($150), and other costs ($670). Modelled cost adjusted for per person with *pulmonary* TB treated ($1,775).
MDR-TB treatment (standard)	Per person initiating treatment	$5,453	Average cost of 20-month standard treatment with: 12 Bdq Lfx/Mfx Lzd Cfz Cs/Dlm Imp/Amx/Clv, 8 Bdq Lfx/Mfx Lzd Cfz Cs. Incorporates cost of drugs ($2,455), inpatient costs ($180), outpatient and monitoring costs ($2169), treatment observation costs ($350), adverse event management ($250), and other costs ($50). Modelled cost adjusted for per person with *pulmonary* TB treated ($6,729).
MDR-TB treatment (shorter regimens)	Per person initiating treatment	$3,337	Weighted average cost of 6-to-9-month shorter regimens with: Bdq, Cfz, Lzd, Lfx, Cs; Bdq, Cfz, Lzd, Lfx, Dlm; BPaLM; BPaL; BPaL C. Incorporates cost of drugs ($1,144), inpatient costs ($120), outpatient and monitoring costs ($1423), treatment observation costs ($350), adverse event management ($250), and other costs ($50). Modelled cost adjusted for per person with *pulmonary* TB treated ($4,117).
XDR-TB treatment (standard)	Per person initiating treatment	$5,767	Based on 20-month standard treatment with 12 Bdq Lfx/Mfx Lzd Cfz Cs/Dlm Imp/Amx/Clv & 8 Bdq Lfx/Mfx Lzd Cfz Cs Amx/Clv. Incorporates cost of drugs ($2,768), inpatient costs ($180), outpatient and monitoring costs ($2169), treatment observation ($350), adverse event management ($250), and other costs ($50). Modelled cost adjusted for per person with *pulmonary* TB treated ($54,000).

Notes: BPaL, novel all-oral 6-9 month regimen composed of bedaquiline, pretomanid, linezolid; BPaLM, novel all-oral 6-month regimen composed of bedaquiline, pretomanid, linezolid and moxifloxacin; DS, drug susceptible; NTP, National TB Protection Program of Tajikistan; TB, tuberculosis; MDR, multi-drug resistant; XDR, extensively drug-resistant.
Source: Unless indicated, data provided by the National TB Protection Program of Tajikistan, 2023

APPENDIX E. DETAILED MODEL FINDINGS

Table E1. Annual TB program spending in baseline and optimized spending scenarios (USD)

	Baseline 2022	Optimized 75% spending	Optimized 100% spending	Optimized 125% spending	Optimized 150% spending
TB preventative therapy for 0-4	$310,620	$3,166,270	$3,569,006	$4,513,697	$4,685,721
TB preventative therapy for 5-14	$394,192	$147,822	$3,948,658	$8,664,569	$8,950,264
TB preventative therapy for 15-64	$44,660	$16,748	$22,330	$22,330	$6,707,590
TB preventative therapy for PLHIV	$384,398	$288,299	$384,398	$384,398	$384,398
BCG vaccination	$316,063	$324,349	$316,063	$316,063	$356,572
Mass screening (school-based)	$254,501	$95,438	$127,251	$127,251	$127,251
Mass screening (community TB days)	$152,701	$57,263	$76,350	$76,350	$76,350
Contact tracing	$15,398,122	$5,774,296	$7,699,061	$7,699,061	$7,699,061
Active case finding (prisoners)	$405,141	$151,928	$202,570	$405,143	$408,541
Active case finding (community-based)	$217,837	$1,198,038	$1,350,223	$1,809,643	$1,622,848
Active case finding (hospitals and primary health care)	$634,094	$827,518	$824,341	$827,063	$829,462
DS-TB treatment	$6,383,922	$6,893,775	$6,990,663	$7,412,842	$7,266,359
MDR-TB standard treatment	$1,297,876	$486,703	$648,938	$648,938	$689,671
MDR-TB shorter treatment regimens	$510,490	$805,449	$818,672	$884,286	$800,654
XDR-TB standard treatment	$547,818	$205,432	$273,909	$273,909	$273,909
Total	$27,252,434	$20,439,326	$27,252,434	$34,065,543	$40,878,651

Source: Optima TB Tajikistan model outputs, 2023

Notes: BCG, Bacillus Calmette-Guerin; DS, drug susceptible; TB, tuberculosis; MDR, multi-drug resistant; PLHIV, people living with HIV; TPT, TB preventive treatment; XDR, extensively drug-resistant.

Table E2. Annual TB program coverage in baseline and optimized spending scenarios

	Coverage definition used	Baseline 2022	Optimized 75% spending	Optimized 100% spending	Optimized 125% spending	Optimized 150% spending
TB preventative therapy for 0-4	Per person with early latent TB treated	247,891	254,389	247,891	247,891	258,555
TB preventative therapy for 5-14	Per person with early latent TB treated	296	3,022	3,406	4,307	4,472
TB preventative therapy for 15-64	Per person with early latent TB treated	255	96	2,556	5,608	5,793
TB preventative therapy for PLHIV	Per person with early latent TB treated	14	5	7	7	2,148
BCG vaccination	Number vaccinated	965	724	965	965	965
Mass screening (school-based)	Number screened	5,000	1,875	2,500	2,500	2,500
Mass screening (community TB days)	Number screened	3,000	1,125	1,500	1,500	1,500
Contact tracing	Number diagnosed	281	105	140	140	140
Active case finding (prisoners)	Relative to *baseline screening*	100%	36%	50%	100%	100%
Active case finding (community-based)	Number diagnosed	614	2,288	2,385	2,550	2,499
Active case finding (hospitals and primary health care)	Relative to *baseline screening*	100%	130%	130%	130%	130%
DS-TB treatment	Number treated	2,930	3,755	3,801	3,967	3,911
MDR-TB standard treatment	Number treated	154	72	96	96	102
MDR-TB shorter treatment regimens	Number treated	124	189	192	206	188
XDR-TB standard treatment	Number treated	2	3	3	3	3

Source: Optima TB Tajikistan model outputs, 2023

Notes: BCG, Bacillus Calmette-Guerin; DS, drug susceptible; TB, tuberculosis; MDR, multi-drug resistant; PLHIV, people living with HIV; XDR, extensively drug-resistant.

Table E3.Optima TB projected incidence of TB , incidence per 100,000 people and TB-related deaths by spending scenario from 2022 to 2030

	2022	2023	2024	2025	2026	2027	2028	2029	2030
NEW AND RELAPSE TB CASES									
Baseline spending	8,069	7,998	7,909	7,843	7,792	7,749	7,716	7,691	7,675
Optimized 75% spending	8,069	7,998	7,851	7,669	7,486	7,303	7,132	6,976	6,845
Optimized 100% spending	8,069	7,998	7,792	7,507	7,229	6,953	6,695	6,479	6,279
Optimized 125% spending	8,069	7,998	7,710	7,278	6,859	6,567	6,357	6,160	5,978
Optimized 150% spending	8,069	7,998	7,630	7,056	6,518	6,133	5,811	5,500	5,207
TB INCIDENCE PER 100,000 PEOPLE									
Baseline spending	82	81	78	76	74	72	71	69	68
Optimized 75% spending	82	81	78	76	73	70	67	64	62
Optimized 100% spending	81	78	75	71	67	64	60	57	55
Optimized 125% spending	81	78	74	69	64	60	57	55	52
Optimized 150% spending	81	78	73	67	61	56	52	49	45
ACTIVE DR-TB CASES									
Baseline spending	1,157	1,147	1,134	1,125	1,118	1,112	1,107	1,103	1,100
Optimized 75% spending	1,157	1,147	1,124	1,096	1,068	1,040	1,014	991	972
Optimized 100% spending	1,157	1,147	1,114	1,068	1,024	981	942	910	881
Optimized 125% spending	1,157	1,147	1,100	1,029	961	917	887	860	835
Optimized 150% spending	1,157	1,147	1,089	998	915	859	814	771	731
TB-RELATED DEATHS									
Baseline spending	954	940	929	934	937	933	930	929	929
Optimized 75% spending	954	940	913	869	806	753	735	719	704
Optimized 100% spending	954	940	912	865	798	740	709	681	655
Optimized 125% spending	954	939	910	856	781	719	674	630	592
Optimized 150% spending	954	939	910	858	784	719	661	604	557

Source: Optima TB Tajikistan model outputs, 2023
Notes: DR, drug-resistant; TB, tuberculosis. Baseline spending refers to continued spending and allocation based on 2022 baseline.

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