

DTP BOOST

DEMO GUIDE

VACCINATION STRATEGY TOOL

MODELLING THE HEALTH & ECONOMIC
IMPACT OF INTRODUCING DTPCV
BOOSTER DOSES



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DTP Boost

DTP Boost is an interactive web-based tool to inform country-level decision making about the introduction and routine delivery of diphtheria-tetanus-pertussis-containing vaccines (DTPCV) booster doses. The tool allows users to design vaccination strategies to explore the health impact, budget impact, and cost-effectiveness of introducing DTPCV booster doses in a selected country.

DTP Boost is powered by an integrated epidemiological and health economic model, tailored to the selected country, accounting for differences in existing vaccination schedule, current burden of disease, health systems characteristics, costs of illness and vaccination. Multiple vaccination strategies can be designed, allowing a detailed and interactive exploration of the relative costs and benefits of different numbers of DTPCV booster doses, vaccination coverage levels, introduction approaches (e.g., simultaneous, phased), vaccine formulations and vaccination delivery platforms (e.g., health facility, outreach site, school-based).

DTP Boost was developed by the Modelling and Simulation Hub, Africa (MASHA) at the University of Cape Town in collaboration with the African Field Epidemiology Network (AFENET) and United States Centers for Disease Control and Prevention (U.S. CDC) with guidance from an expert steering committee. The tool has been piloted in Uganda, in partnership with the Ugandan National Program on Immunization (UNEPI).

Using the Demo tool

The full DTP Boost tool uses a live-running model and requires local data to tailor the projections to the selected country. To enable easy exploration of the tool and its key features, a demo version was developed with simplified optionality, default data and a set of pre-run scenarios.

This guide is intended to show the process of using the app with sample scenarios and data. Additional resources are provided in later sections.

Four steps need to be followed to use the app:

1. Set up country profile
2. Calibrate model
3. Design booster strategy
4. Explore and download results

Access and citation

The DTP Boost Demo Tool is available through the link below. **Access to the full tool, as well as support for using it, is available on request.**

<https://masha-app.shinyapps.io/DTPBoostDemo/>

The demo model and application code is available on Github (uct-masha/DTPBoost-Demo)

Suggested citation: Hounsell, RA., Norman, JM., Monyake, R., Silal, SP (2023) DTPBoost-Demo. (Version 1.0.0). Available at: <https://github.com/uct-masha/DTPBoost-Demo/releases/tag/1.0.0>

Contact us

For more information DTP Boost, or to access the full tool, please contact:
masha@uct.ac.za

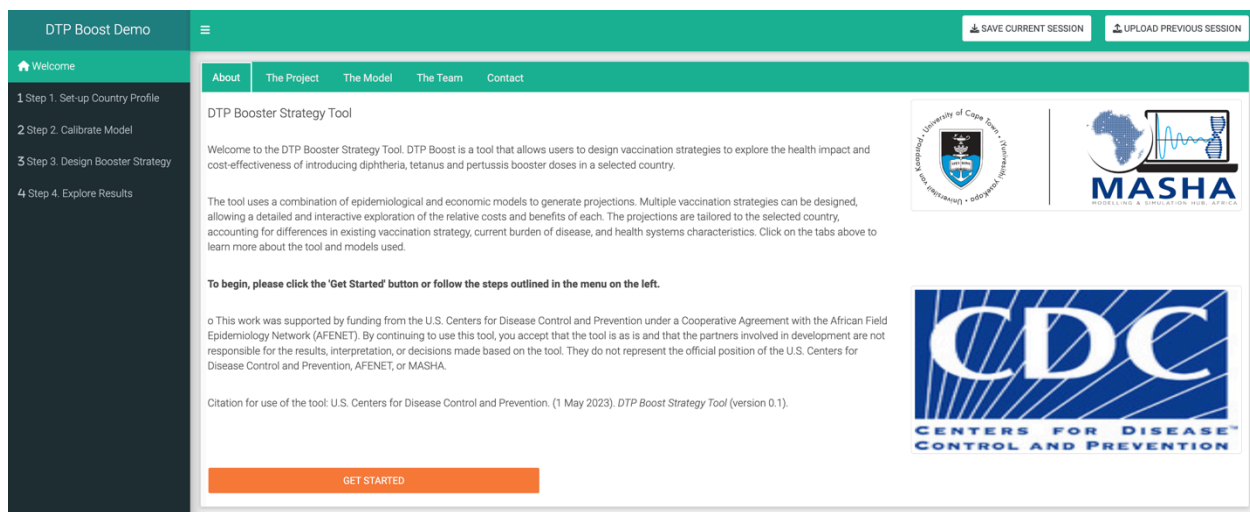
www.masha.uct.ac.za
Modelling and Simulation Hub, Africa (MASHA),
University of Cape Town

Welcome – Landing page

Upon loading the DTP Booster Demo, the welcome screen provides information about the application, including details about the start of the project, the epidemiological and economic model being used, and team details with contact information. This can be accessed on their respective tabs at the top of the page.

On the left of the screen is the application menu detailing the different steps for using the DTP Boost App.

In the upper right corner of the application are two buttons, which allow users to save the current session or upload a previous session. These buttons are always displayed and, in the full version, allow users to resume or review a previously saved session.



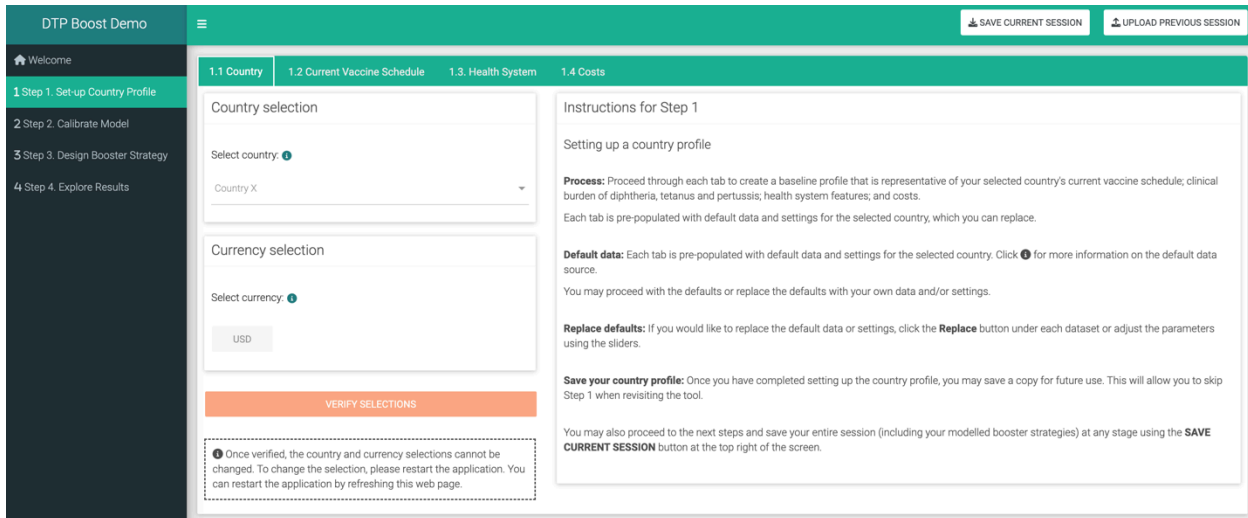
To begin using the demo click the **GET STARTED** button at the bottom of the **Welcome** page on the **About** tab. This will lead to **Step 1. Set-up Country Profile**.

Step 1. Set-up Country Profile

In this section, information provided by the user is used to create a baseline profile that represents the selected country's current vaccine schedule, health system features, and the clinical burden and cost of diphtheria, tetanus, and pertussis.

1.1 Country Selection

For this demo, **Country Selection** and **Currency selection** have been set as Country X and USD respectively. The full use of the application allows for selecting a country of interest and setting the currency to USD or the national currency.



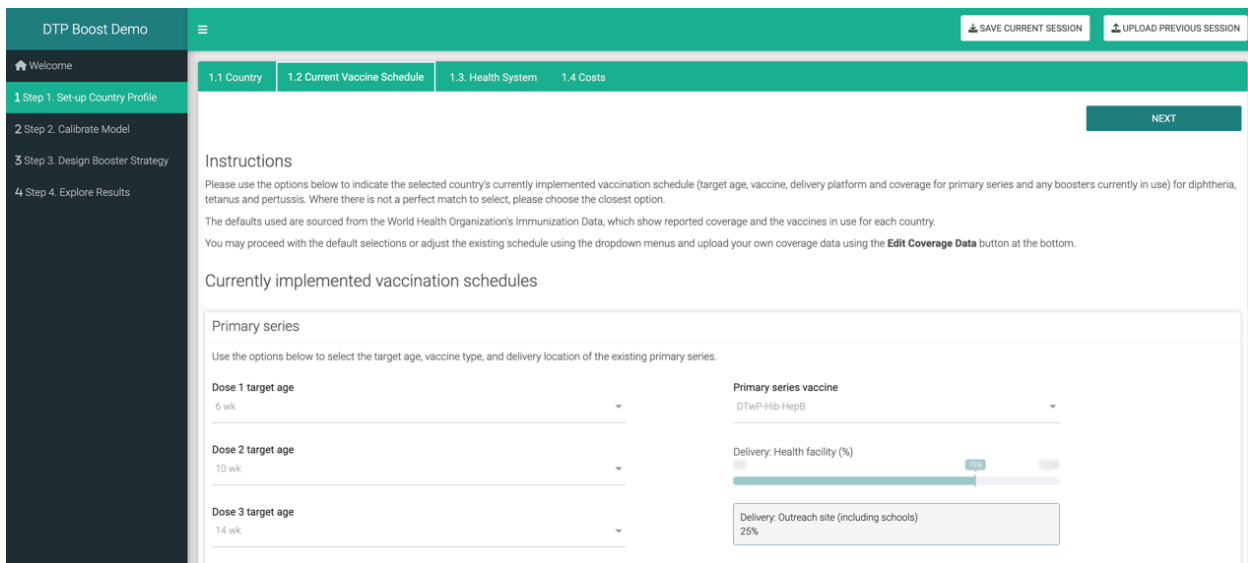
Click on the **VERIFY SELECTIONS** button to proceed to **1.2 Current Vaccine Schedule**.

1.2 Current Vaccine Schedule

This page provides the options to describe the selected country's currently implemented vaccination schedule for diphtheria, tetanus, and pertussis. This includes the primary series and any boosters in current use.

Primary Series

For Country X, the primary series is given as the DTwP-Hib-HepB (pentavalent) vaccine at 6, 10, and 14 weeks. The delivery location of the primary series is set at 75% at the health facility, and the remaining 25% is delivered through outreach sites, which includes schools. In this example, no existing booster vaccination is present and is specified to be 'none'. Maternal tetanus and diphtheria vaccination as part of antenatal care (ANC) is specified to be as Td and delivered via health facilities at 75%.



Coverage

Sample vaccine coverage data for Country X is provided in the Coverage section. Default values are taken from the WHO Global Health Observatory database for the coverage of the primary series, booster doses, tetanus toxoid-containing vaccine with at least two doses in reproductive-age women (TTCV2), and antenatal care coverage with at least one visit. Users can edit coverage data to replace values in the full application.

Booster vaccination

Use the options below to select the target age, vaccine type, and delivery location of any existing booster doses.

Early childhood booster target age None	Early childhood booster vaccine DTwP-Hib-HepB	Delivery: Health facility (%) <input type="range" value="75%"/>	Delivery: Outreach site (including schools) 25%
Child booster target age None	Child booster vaccine Td	Delivery: Health facility (%) <input type="range" value="85%"/>	Delivery: Outreach site (including schools) 85%
Adolescent booster target age None	Adolescent booster vaccine Td	Delivery: Health facility (%) <input type="range" value="85%"/>	Delivery: Outreach site (including schools) 85%
Maternal vaccination (via ANC) Td		Delivery: Health facility (%) <input type="range" value="75%"/>	Delivery: Outreach site (including schools) 25%

Coverage

Please review coverage data in the table below. Either proceed with the default values or use the EDIT COVERAGE DATA button to replace the values in the table.

Year	Dose 1	Dose 2	Dose 3	Early childhood booster	Child booster	Adolescent booster	ANC*	TTCV2
2022	96.0%	93.5%	91.0%	0.0%	0.0%	0.0%	80.0%	50.0%
2021	96.0%	93.5%	91.0%	0.0%	0.0%	0.0%	80.0%	50.0%
2020	96.0%	93.5%	91.0%	0.0%	0.0%	0.0%	80.0%	50.0%
2019	96.0%	95.0%	94.0%	0.0%	0.0%	0.0%	80.0%	50.0%
2018	97.0%	95.5%	94.0%	0.0%	0.0%	0.0%	80.0%	50.0%
2017	97.0%	95.5%	94.0%	0.0%	0.0%	0.0%	80.0%	50.0%

* If maternal vaccination is currently implemented, default vaccination coverage for the first dose will be 'Antenatal care coverage - at least 1 visit' based on WHO Global Health Observatory data. For dose 2 and above, TTCV2 data will be used.

Click the **NEXT** button at the upper right corner to proceed to **1.3 Health System**.

1.3 Health System

In this section, the user can set values for the probabilities of the treatment and reporting of diphtheria, tetanus, and pertussis. Users can slide and adjust each value according to each disease. For the demo tool, the values have been predetermined and set accordingly. Under **DTP Treatment**, the probability of cases being treated in the outpatient or inpatient setting reflects how the population in the country seeks and accesses medical care. Under **DTP Reporting**, the probability of symptomatic cases being diagnosed and reported approximate disease reporting systems and surveillance reports in the country.

Please note: The probabilities for cases being recognised or diagnosed and treatment in the respective setting may require estimation and expert input. It is assumed that tetanus results in severe cases only. The notes section may be used to add notes on sources and any other relevant details.

Click the **NEXT** button to proceed to **1.4 Cost**.

1.4 Cost

The cost page provides the user with options to indicate cost data for DTP vaccination and cost of illness estimates. The default discount rate used is 3.5%. The user can change this value. The provider (government) perspective is used. No societal costs are included.

The **Cost of Vaccination** is further separated into the cost of routine vaccination delivery by dose and the unit cost of the vaccine by dose. The costs for vaccine delivery location are further split by delivery location, either at a health facility or outreach site (including schools). It is assumed that the unit cost of these vaccines will be constant given the history of UNICEF prices for these vaccines. Costs are incremental.

Welcome

1.1 Country 1.2 Current Vaccine Schedule 1.3. Health System 1.4 Costs

1 Step 1. Set-up Country Profile 2 Step 2. Calibrate Model 3 Step 3. Design Booster Strategy 4 Step 4. Explore Results

Instructions

Please use the options below to indicate relevant cost data for DTP immunisation and cost of illness estimates. You can use the defaults or replace with your own cost estimates using the slider and input boxes below. For more details, please click the information button.

Discount rate (%)
3.50

Cost of vaccination (delivery + vaccine)

Cost of routine delivery (per dose)

Average cost per dose of routine vaccine delivery (delivery only, excluding vaccine cost)

Series	Health facility (USD)	Outreach (USD)	Delivery costs paid directly by government (%)
Primary series	1.701	1.425	50%
Maternal vaccination (via ANC)	1.701	1.425	50%

Cost of vaccines (per dose)

Cost of vaccine per dose (unit cost of vaccine only, no delivery cost)

Series	DTwP-Hib-HepB (USD)	Cost of vaccines paid directly by government (%)
Primary series	0.800	50%

Under **Cost of illness**, the indicated costs include the average cost per inpatient case and the average cost per outpatient case. The cost is shown from the provider's perspective (the government) and includes direct costs only.

Cost of vaccines (per dose)

Cost of vaccine per dose (unit cost of vaccine only, no delivery cost)

Series	DTwP-Hib-HepB (USD)	Td (USD)	Cost of vaccines paid directly by government (%)
Primary series	0.800		50%
Maternal vaccination		0.110	50%

Cost of illness

Illness	Cost per outpatient case (USD)	Cost per inpatient case (USD)
Diphtheria	50.000	111.000
Pertussis	50.000	111.000
Tetanus	50.000	125.000

The default values provided in this demonstration for Country X are sample values only. Users may draw from costing studies, published literature, databases, or official documents to source cost data. If no data are available, estimates from a similar context or illness may be used as a proxy.

This completes **Step 1. Set-up Country Profile**.

Click the **NEXT** button to proceed to **Step 2. Calibrate Model**.

Step 2. Calibrate Model

This section allows the user to calibrate the model to the chosen setting. Model fitting is conducted to validate that the transmission model produces estimates that are similar to observed data. A fitted model adds validity to predictions of the impact of vaccination. The reporting rate specified in the **Health System** section will be used to correct for under-reporting of diagnosed cases.

2.1 Select data

In this section, the next step is to select a dataset for calibration. The two main data options are the WHO observed incidence data or the Global Burden of Disease incidence estimates. Due to the nature of diphtheria occurring in outbreaks, the calibration is applied only to pertussis and tetanus. Users must check if the datasets are sufficient and plausible for both pertussis and tetanus to fit the model. Users may hover the cursor over the figures for additional information on the values per year.

In the full tool, users may upload their own data to replace the default data using a template and by selecting **OWN DATA** in the **Choose a dataset for calibration** section of the page.

For this demo the GBD estimates have been selected for the dataset to be used.

The screenshot shows the '2.1 Select data' section of the tool interface. At the top, there is a green navigation bar with three tabs: '2.1 Select data' (active), '2.2 Calibration', and '2.3 Assessing uncertainty'. Below the navigation bar, the 'Instructions' section contains the following text: 'Please use the options below to select the incidence dataset to be used for model fitting. Model fitting is conducted to validate that the transmission model produces estimates that are similar to observed data. A fitted model adds validity to predictions of the impact of vaccination. The reporting rate specified in the Health System section will be used to correct for under-reporting of diagnosed cases. Two data options are available: 1) WHO observed incidence data and 2) Global Burden of Disease incidence estimates. If you prefer to upload your own incidence data, you may do so in the 'Upload your data' box below. Given that unpredictable external drivers often seed diphtheria outbreaks, calibration is applied to pertussis and tetanus only. It is important to interrogate the datasets to determine if data are valid given local experience for both pertussis and tetanus to fit the model.'

Below the instructions is the 'Choose a dataset for calibration' section. It contains the text: 'Use the buttons to select a dataset for calibration that best fits your country's profile.' There are three radio button options: 'WHO', 'GBD' (which is selected), and 'OWN DATA'. A green button labeled 'GO TO CALIBRATION' is positioned to the right of the radio buttons. At the bottom of this section, there is a note: 'The plots below display the WHO data and GBD estimates to help you select the best approach. The option to upload your own data is shown under the heading Upload your data.'

Click on **GO TO CALIBRATION** to proceed to **Step 2.2 Calibration**.

2.2 Calibration

The aim of the manual calibration is to adjust the slider values for both pertussis and tetanus until the model output resembles the data. The **RUN THE MODEL** button must be clicked after each adjustment of the sliders.

This manual calibration is a simple form of face validation, which qualitatively assesses if the model is an adequate representation of the data.

The screenshot shows the 'DTP Boost Demo' application interface. The top navigation bar includes 'SAVE CURRENT SESSION' and 'UPLOAD PREVIOUS SESSION' buttons. The left sidebar lists the steps: '1 Step 1. Set-up Country Profile', '2 Step 2. Calibrate Model' (highlighted), '3 Step 3. Design Booster Strategy', and '4 Step 4. Explore Results'. The main content area is titled '2.2 Calibration' and contains 'Instructions' and a 'DTP Estimated Incidence' chart. The instructions state: 'The aim of the manual calibration is to adjust the slider values for both pertussis and tetanus until the model output resembles the data. You will need to press the **RUN THE MODEL** button after each adjustment of the sliders. This manual calibration is a simple form of face validation, which qualitatively assesses if the model is an adequate representation of the data. If you are happy with your calibration, press the **ACCEPT THIS CALIBRATION AND MOVE ON** button to move to Step 3: Booster Strategy Design.' The chart displays 'Tetanus' incidence (left y-axis, 0-1400) and 'Pertussis' incidence (right y-axis, 0-400k) from 2010 to 2018. It includes two sliders for 'Tetanus transmission tuning parameter' and 'Pertussis transmission tuning parameter', and a 'RUN THE MODEL' button. A legend at the bottom of the chart identifies 'Tetanus model value' (green line) and 'Pertussis model value' (red line). A 'ACCEPT THIS CALIBRATION AND MOVE ON' button is located at the bottom right of the chart area.

Once calibration is satisfactory, click on the **ACCEPT THIS CALIBRATION AND MOVE ON** button to proceed to **Step 3. Design Booster Strategy**.

Information is provided in **2.3 Assessing uncertainty** for factors that users may need to consider in using the app.

Step 3. Design Booster Strategy

3.1 Instructions

The list of vaccination options and settings are summarised to aid in designing a booster strategy. Users may design, save, and simulate as many strategies as they would like to compare and explore in the results section (Step 4).

Click on the **NEXT** button to proceed to section **3.2 Build a vaccination strategy**.

3.2 Build a vaccination strategy

Build package

To design a vaccination strategy, users can toggle the options to be included. Once in the 'on' position, a settings button will become visible. This allows adjustment of the details of each option. Defaults and a limited set of options are provided for this demo. In the full use application, all details should reflect your selected strategy and context.

Cost of introduction

Once the desired vaccination package has been built, the anticipated cost of introducing new dose(s) must be indicated. This detail only needs to be entered once. The introduction cost is the average total cost of introducing new vaccine dose(s) in a given year. This is a fixed cost regardless of the number of doses introduced in the introduction year. Users have the option to indicate whether this cost will only be incurred once, even if additional booster doses are introduced in future years.

Save & simulate

Once done with designing a strategy, users can name it in the box located at the bottom right. For this demo strategy, names have been set for ease of use.

The screenshot displays the '3.2 Build a vaccination strategy' interface. It includes a top navigation bar with 'SAVE CURRENT SESSION' and 'UPLOAD PREVIOUS SESSION' buttons. The main content area is divided into several sections:

- DTP Booster doses:** Includes toggle switches for 'Early childhood booster' (checked), 'Child booster', and 'Adolescent booster'. A 'SETTINGS' button is visible.
- Other DTP Vaccinations:** Includes a toggle for 'Maternal vaccination'.
- Target, Timeline, Delivery, and Cost of routine delivery (per dose):** A central panel with sliders and input fields for 'Age group' (18 mth), 'Start year' (2024), 'Vaccine' (DTwP-Hib-HepB), 'Operational coverage' (50%), 'Health facility (%)' (25%), 'Outreach site (%)' (20%), 'Health facility (USD)' (1.701), and 'Outreach (USD)' (1.425).
- Cost of introduction (total):** A section with a text box for 'Average total once-off cost of introducing new vaccine dose(s) in a given year (fixed cost regardless of number of doses introduced in the introduction year.)' and a 'Fixed cost (USD)' input field set to '2,000,000.000'. It also includes a slider for 'Proportion of fixed introduction costs paid directly by government' set to 50%.
- Save and simulate strategy:** A bottom right box with 'Strategy name:' input fields containing 'EC2440' and 'EC2440', and a green 'RUN' button.

Click the **Run** button. This will direct the user to **Step 4. Explore results**. The strategy will be visible in the results section.

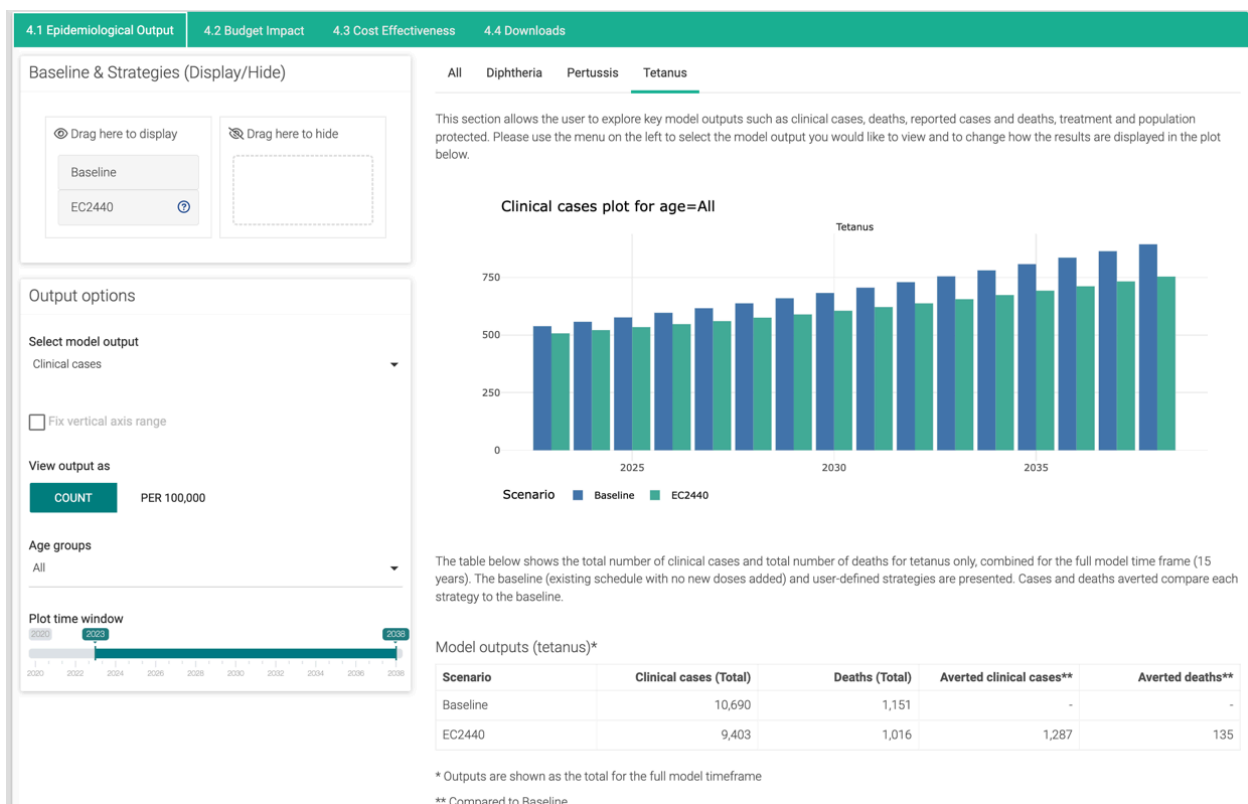
Users may repeat this several times to design and run multiple strategies. To return to Step 3, click on **Step 3. Design Booster Strategy** in the menu on the left side of the screen.

Step 4. Explore Results

4.1 Epidemiological Output

The controls on the left displaying the **Baseline & Strategies** can be used to filter the results. The **Output options** allow the selection of model output such as population protected, clinical cases, and deaths. Other options include the preferred output measure, age groups and time window to be displayed. Epidemiological results for all diseases, and for each specific disease, can be viewed by clicking on the tabs on the upper right side of the page. A table of projected epidemiologic results is shown at the bottom right of the page. Users can hover over the figures for additional details and to save the figures as png for offline use.

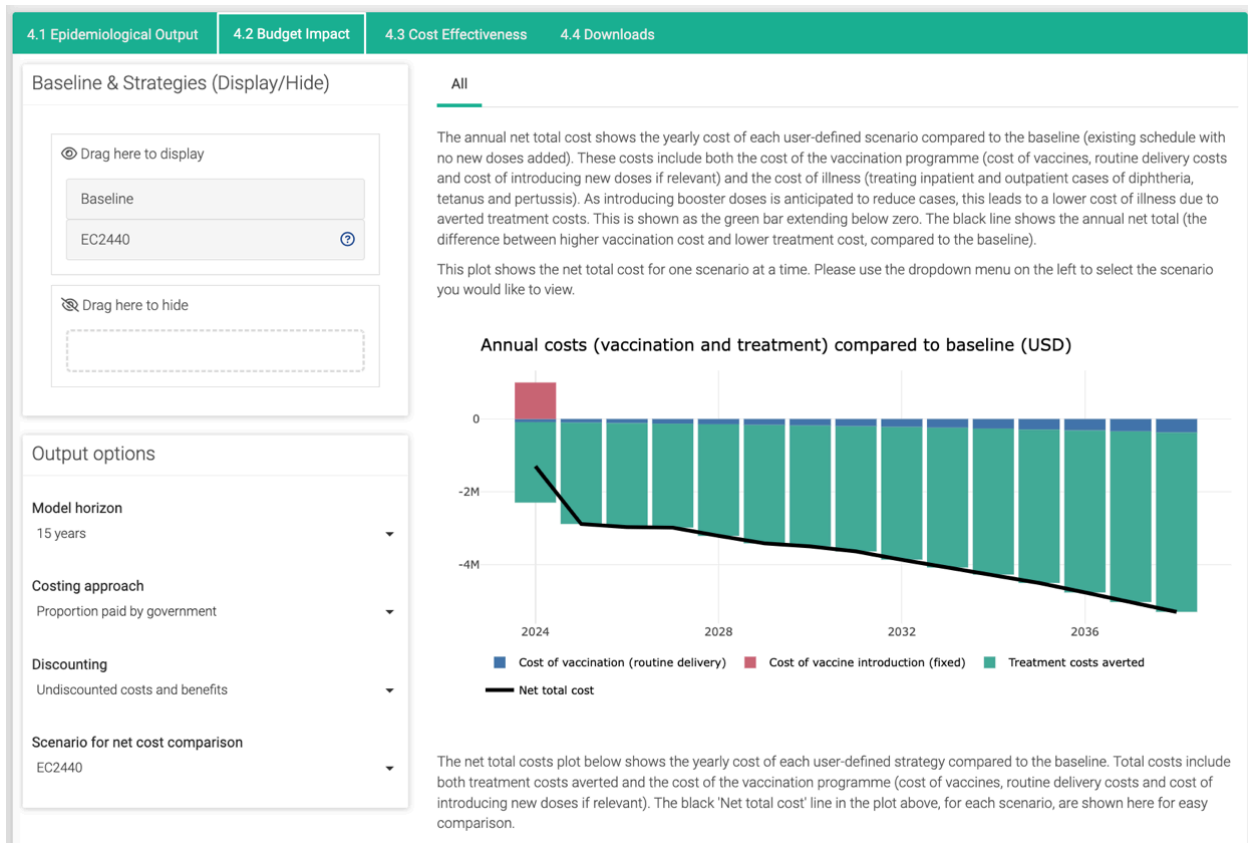
The full version of the tool has additional output options, such as reported cases, reported deaths, number of inpatient cases, and number of outpatient cases. There are also more aggregate age categories available for exploring the outputs (e.g. <1 year olds, <15 year olds, and all 5-year age bands).



4.2 Budget Impact

The budget impact tab shows three plots (Annual costs compared to the baseline, Net total cost compared to the baseline, Total annual cost of vaccination), a table of projected costs and the output option controls. Details of what each presents is captured in the tool.

Output can be viewed for a 10 year or 15 year time horizon; and either for the full cost or only the proportion paid by the government.



4.3 Cost Effectiveness

The cost effectiveness tab shows one plot (Incremental cost effectiveness) and a table of effectiveness outputs. Users have the option of viewing the results for all diseases or for a specific disease individually by clicking on the tabs. Options to adjust for the model output, model horizon, costing approach, and discounting is available in the **Output options** section on the left of the screen.

4.1 Epidemiological Output
4.2 Budget Impact
4.3 Cost Effectiveness
4.4 Downloads

Baseline & Strategies (Display/Hide)

👁️ Drag here to display

Baseline

EC2440 🔍

🙋 Drag here to hide

All
Diphtheria
Pertussis
Tetanus

These results show the cost-effectiveness of the vaccination programme in terms of cost per clinical case averted and cost per death averted, for each user-defined strategy compared to baseline (existing schedule with no new doses added). The total cost includes both the cost of the vaccination programme (cost of vaccines, routine delivery costs and cost of introducing new doses if relevant) and the cost of illness (treating inpatient and outpatient cases of diphtheria, tetanus and pertussis). Clinical cases and deaths are counted for diphtheria, tetanus and pertussis combined.

Please use the dropdown menu on the left to select whether you would like to view the cost-effectiveness based on the entire cost or only the proportion of the cost paid by government (based on the inputs given by the user in Step 1 and Step 3).

Incremental Cost Effectiveness, 2024 - 2038 (USD)

Note: If the net total cost (plot above) or the cost per clinical case averted/cost per death averted (table below) is negative, the strategy is cost-saving. This happens when the amount saved through averted treatment costs is greater than the amount spent implementing the new vaccination strategy.

Effectiveness outputs (diphtheria, tetanus and pertussis)*

Scenario	Total cost	Cost of vaccination	Cost of illness	Clinical cases (Total)	Deaths (Total)	Cost per clinical case averted**	Cost per death averted**
Baseline	356,972,000	100,033,000	256,939,000	5,380,000	7,620	-	-
EC2440	313,073,000	97,322,000	215,752,000	4,500,000	6,450	-749	-562,000

* Outputs are shown as the total for the full model timeframe
** Compared to Baseline

Output options

Select model output (cost effectiveness)
Clinical cases ▼

Model horizon
15 years ▼

Costing approach
Full cost (donor and government) ▼

Discounting
Discounted costs and benefits ▼

4.4 Downloads

Results can be downloaded for use offline as a PDF or in csv format for further analysis.

To save additional figures in various sections or selections, such as specific output, costing approach or age category, hover over any plot in the tool to download it as a png image.

Resources

Use the tables below as a guide in collecting the required data inputs for the full use of the app. Consider multiple sources and higher or lower values for comparison.

Table 1. Data Needs – Country Profile

Parameter	Point Estimate	Lower Limit	Higher limit	Sources
Existing Primary Series				
Primary series dose schedule & ages given				
Vaccine type/components				
Health Facility Delivery (%)				
Outreach site (%)				
Existing Booster Vaccination				
Booster: Early Childhood coverage				
Delivery: Health Facility (%)				
Delivery: Outreach site (%)				
Vaccine type/components				
Booster: Child booster coverage				
Delivery: Health Facility (%)				
Delivery: Outreach site (%)				
Booster: Adolescent				
Delivery: Health Facility (%)				
Delivery: Outreach site (%)				
Maternal vaccination: Td / Tetanus toxoid				
Delivery: Health Facility (%)				
Delivery: Outreach site (%)				
Vaccine Coverage (1985 to current year)				
Primary Series (Dose 1, 2, 3)				
Early Childhood booster				
Child booster				
Adolescent booster				
Antenatal care coverage – at least 1 visit (ANC)				
Tetanus toxoid containing vaccine ≥ 2 doses				
DTP Treatment				
Diphtheria				
Probability mild case treated OPD				
Probability severe case treated (inpatient)				
Pertussis				
Probability mild case treated OPD				
Probability severe case treated (inpatient)				
Tetanus				
Probability severe case treated (inpatient)				
DTP Reporting				

Diphtheria				
Probability symptomatic cases being diagnosed				
Probability deaths being reported				
Pertussis				
Probability symptomatic cases being diagnosed				
Probability deaths being reported				
Tetanus				
Probability symptomatic cases being diagnosed				
Probability deaths being reported				

Table 2. Data needs - Costs

Parameter	Point Estimate	Lower Limit	Higher limit	Sources
COSTS				
Discount rate (%)				
Cost paid by government (%)				
Primary series cost (USD)				
Health facility				
Outreach				
Maternal vaccination via ANC				
Health facility				
Outreach				
Cost of vaccine per dose				
Primary series				
Maternal vaccination (Td)				
Other DTP containing vaccines				
COST OF ILLNESS (USD)				
Diphtheria				
Cost per OPD case				
Cost per inpatient case				
Pertussis				
Cost per OPD case				
Cost per inpatient case				
Tetanus				
Cost per OPD case				
Cost per inpatient case				
Cost of introduction				
Fixed cost (USD)				

Links to databases and relevant resources

[WHO Immunization Data Portal](#)

Provides country level vaccine schedules, vaccine coverage data, and disease incidence.

[Immunization Delivery Cost Catalogue](#)

This resource provided by the Immunization Costing Action Network (ICAN) and ThinkWell, includes cost information on routine immunization and immunization campaign costing studies from various contexts. Other links and resources are available on the Immunizationeconomics.org website such as cost of illness studies.

[Market Information for Access to Vaccines \(MI4A\)](#)

The MI4A vaccine purchase database includes information on vaccine prices as reported by 150 countries through the WHO/UNICEF Joint Reporting Form, and is updated yearly.

[UNICEF Vaccines Pricing Data](#)

Database of vaccine prices procured by UNICEF according to vaccine and as awarded price per dose in US Dollars. Includes data from previous years with consultation from UNICEF suppliers.

[WHO Position Papers](#)

These provide the basis for primary and booster doses in [diphtheria](#), [tetanus](#), and [pertussis](#).