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Introduction to VICE

• The Vaccine Introduction Cost-Effectiveness (VICE) calculator is an Excel-based model for evaluating the cost-effectiveness of vaccination programs
  – Currently calibrated for oral cholera vaccine but applicable to any disease intervention

• VICE is fully flexible for a variety of user-specified parameters for disease epidemiology, population demographics, and intervention characteristics
  – Can be stratified into up to 4 subpopulations that may vary in demographic and epidemiological characteristics to compare different scenarios

• In addition to calculating estimated health and economic quantitative outcomes, VICE automatically generates a series of graphs to visualize vaccination interventions and health & economic outcomes, including sensitivity analyses
Cost-Effectiveness

• The Cost-Effectiveness of a health intervention is the ratio of **Intervention Cost** to **Health Benefit**
  – The Intervention Cost is the Total Intervention Cost less the Incremental Cost Averted
    • How much an intervention costs minus how much that intervention saves in medical costs and/or lost time and wages.
  – The Health Benefit is measured by DALYs (Disability Adjusted Life Years). DALYs Averted is the Baseline DALYs less the DALYs Averted by the Intervention.
    • DALYs are a widely used metric for the burden of disease and is a sum of Years of Life Lost (YLL) and Years Lost to Disability (YLD) [WHO, Global Burden of Disease Study]

• If the Cost per DALY Averted is less than 3 times the Gross Domestic Product per Capita, a given intervention is **cost-effective** [WHO CHOICE]
Calculating DALYS

• **Years Lost to Disability (YLD) Averted** \(_{i,t} = \)

\[ \left( 1 - \text{CaseFatalityRatio}_i \right) \times \text{VaccineEfficacy}_t \times \text{Incidence}_i \times \text{Length of Illness} \times \text{DALY Weight} \]

• **Years of Life Lost (YLL) Averted** \(_{i,t} = \)

\[ \left( \frac{\text{CaseFatalityRatio}_i \times \text{VaccineEfficacy}_t \times \text{Incidence}_i}{\text{Discount}} \right) \times \left[ 1 - \exp\left( -\text{Discount} \times \text{Life Expectancy}_i \right) \right] \]

• **DALYs Averted** \(_{i,t} = \text{Years Lost to Disability}_{i,t} + \text{Years of Life Lost}_{i,t} \)

• **Total DALYs Averted** \(_i = (t=0, \text{Duration of Immunity}) \sum (\text{DALYs}_{i,t})/(1+\text{Discount})^t \)

• **Cost Effectiveness Ratio** = Net Cost / DALYs Averted

Where \( t = \) time in years and \( i = \) subgroup \( i \)

Welcome to the VICE Calculator. This calculator is used to determine the cost effectiveness of a vaccine when it is delivered to a group of people who are at risk of cholera. Although VICE was developed specifically for cholera, it may find usefulness for other diseases where a specific intervention is intended to reduce the probability of the disease from occurring.

Cost effectiveness is a concept in which one attempts to measure the amount of money required to avert a case of cholera, or avert a death from cholera, or to avert a DALY. A vaccine will obviously be more cost effective if the vaccine is very inexpensive, but other factors also contribute to this calculation. If the vaccine is given to people who have a high risk for the disease, the vaccine will prevent more cases than if it is given to persons with a low risk. For example, if cholera vaccine is given to persons in the USA, even a vaccine that gives excellent protection and is very cheap vaccine will not be cost effective because people in the USA are not likely to get cholera whether or not they have been vaccinated. On the other hand, a vaccine which gives only moderate protection will be highly cost effective if it is provided to persons at high risk, especially if the vaccine is inexpensive.

The VICE Calculator examines the different variables needed to determine the cost effectiveness of cholera vaccine and provides an output which shows just how cost effective the vaccine is. In other words, the cost effectiveness of cholera vaccine depends on the situation where it is to be used. Since each situation is different, the cost effectiveness will also be different. Although the cost of the current cholera vaccine (Shanchol) is relatively fixed, future vaccines may be more or less expensive, so this also is taken into consideration.

To use VICE, you will need to estimate the values for the different variable and enter them into the calculator. In some cases you will know the values, in others, you will need to provide your best estimate or a likely probability. The following tables will provide some guidance as to reasonable numbers you may want to enter depending on the situation. VICE assumes that the number of people you want to protect is 100,000. If this is not the correct number, you will need to make an adjustment for the total population.

Here is where you will enter the numbers VICE will use to do the calculations:

- **What is the cost of the vaccine per dose?** $1.85 (Shanchol currently costs $1.85 per dose, but other similar vaccines might cost more or less)
- **How many doses of vaccine do you plan to give to each person?** 2 (Two doses are recommended; however, some studies are testing a single dose to see how well this works)
- **What is the cost per dose to deliver the vaccine to the people?** $1.00 (The current estimate is $1.00, but if a program is very efficient, this might be less)
- **How many years do you expect the vaccine to protect?** 3 (In Kolkata India, the vaccine protected for at least 5 years. This might be more or less in other areas)
- **If a patient gets cholera, how much will it cost to treat the patient?** $25.00 (Medical costs are very different in different areas. Generally one can assume this value will be the cost for 2 - 3 days in hospital)
- **What is the GDP per capita of the country?** $700.00

Now VICE assumes that you may want to give vaccine to different groups with different characteristics. You can divide the population into up to four groups. These might be different age groups, or social groups, or geographic groups. If you want to keep it simple, you do not have to divide the population into these groups, just put a zero for groups 2, 3, and 4 if you have only one group.

If you want to define different groups, what proportion of the population is in group 1? 100% (As a default, we put everyone in group one, but you can divide the population into different groups if this is more appropriate)

The *Entering the Data* tab gives a general description of the VICE Calculator and information about the parameters that can be changed by the user in the cost-effectiveness calculation. This tab is where the user specifies their desired input parameters. These are in green. Changes in this tab are reflected in the *Charts and Tables* tab.
Parameter Definitions

**People Fully Vaccinated**: The number of people in the scenario receiving vaccine. The model does not consider vaccine coverage or wastage.

**Vaccine Purchasing Cost**: The total cost of purchasing (all required doses).

**Vaccine Delivery Cost**: The total cost of delivery (all required doses).

**Duration of Immunity**: How long vaccinated individuals are protected from illness.

**Cost of Illness**: The total cost per disease infection. Whether this is the cost to the private sector, public sector, or both depends on where the funds for the vaccine intervention come. Private costs of illness may include treatment, transportation, and lost income/production while public costs of illness include outpatient or hospitalization treatment at a public hospital.

**Gross Domestic Product per Capita**: National level values available for this estimate from the World Bank.


**Population Distribution**: The percent of the *People Fully Vaccinated* that exists in each Group. For a homogeneous population, 100% of the population should exist in Group 1. To compare heterogeneous populations, percentages summing to 100% can be defined for each Group.

**Incidence**: The disease incidence is the number of people infected per 1,000 per year.

**Case Fatality Ratio**: The percentage of infections that are fatal.

**Vaccine Efficacy**: The percentage reduction in the risk of infection for individuals receiving the vaccine.

**Life Expectancy at Age of Vaccination**: The number of years of additional life expected, on average, at age of vaccination. This allows for comparison of vaccinating different age groups. The World Health Organization has Life Tables, including the Life Expectancy, by country for 5-year age groups.


**Annual Discount Rate**: Economists believe that future health and economic outcomes should be discounted at an annual rate, recommended at 3% per year. DALYs Averted in Year 2 will be 3% less than Year 1.

**Illness Duration**: The length of time, on average, that an illness lasts, in days.

**Disability Weight**: A feature of DALYs that quantifies how disabling a disease or condition is on a scale from 0 to 1. Zero represents no disability and 1 represents death. Moderate to Severe diarrhea has a Disability Weight of 0.202, according to the 2010 Global Burden of Disease Study.

Note on Parameters

• DALYs are very sensitive to changes in the input Parameters
• Cost-Effectiveness is highly context-specific, the user should have valid & reliable demographic and epidemiologic data for the input
• The Output will only be as meaningful as the Input data
• “Economics is a one- or at most a two digit science” (Oskar Morgenstern)
Output Tab “Charts and Tables”

### Cost-Effectiveness Thresholds

<table>
<thead>
<tr>
<th>Threshold Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Vaccine Cost of Purchase &amp; Delivery ($)</td>
<td>$12.10</td>
</tr>
<tr>
<td>Very Cost Effective</td>
<td>$3.44</td>
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<tr>
<td>Cost Effective</td>
<td>38.5%</td>
</tr>
<tr>
<td>Very Cost Effective</td>
<td>116.1%</td>
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<tr>
<td>Cost Effective</td>
<td>1.13</td>
</tr>
<tr>
<td>Very Cost Effective</td>
<td>3.23</td>
</tr>
<tr>
<td>Cost Effective</td>
<td>2.83%</td>
</tr>
<tr>
<td>Very Cost Effective</td>
<td>8.45%</td>
</tr>
</tbody>
</table>

*Parameter values to be Cost-Effective*  
*Numbers rounded*

### Case Fatality Ratio (%)

![Case Fatality Ratio Graph](Graph1.png)

- **Group 1**: 60.2%  
- **Group 2**: 9%  
- **Group 3**: 9%  
- **Group 4**: 9%

### Annual Discount Rate (%)

- **Group 1**: 3%  
- **Group 2**: 5%  
- **Group 3**: 5%  
- **Group 4**: 5%

*The incidence and Case Fatality Ratio of disease are shown. Areas shaded blue are cost or very cost-effective.*

### DALYs Averted

![DALYs Averted Graph](Graph2.png)

- **Group 1**: 4.23  
- **Group 2**: 478  
- **Group 3**: 238  
- **Group 4**: 28.1

*The incidence and Case Fatality Ratio of disease are shown. Areas above and to the right indicate combinations that are cost effective at costs per fully vaccinated individual $1-10.*

### Net Vaccination Cost

![Net Vaccination Cost Graph](Graph3.png)

- **Total**: $97,000.00  
- **Cost Averted**: $9,000.00  
- **Net Cost**: $98,000.00  
- **Net Cases Averted**: 399  
- **Cost per DALY Averted**: $1,175.24

*Limit for Cost-Effectiveness is 1 x GDP per DALY Averted*
Entering values in the “Entering the Data” tab changes the Input to the Cost-Effectiveness calculation.

- **People Fully Vaccinated**: 100,000
- **Vaccine Purchasing Cost ($)**: $3.70
- **Vaccine Delivery Cost ($)**: $2.00
- **Duration of Immunity (Years)**: 3
- **Cost of Illness ($)**: $25.00
- **Gross Domestic Product/Capita**: $700.00

**Population Distribution (% of Total)**
- Group 1: 100%
- Group 2: 0%
- Group 3: 0%
- Group 4: 0%

**Incidence (per 1,000 per year)**
- Group 1: 2.00
- Group 2: 0.00
- Group 3: 0.00
- Group 4: 0.00

**Case Fatality Ratio (%)**
- Group 1: 5.00%
- Group 2: 0.00%
- Group 3: 0.00%
- Group 4: 0.00%

**Vaccine Efficacy (%)**
- Group 1: 70%
- Group 2: 0%
- Group 3: 0%
- Group 4: 0%

**Life Expectancy at Age of Infection (Years)**
- Group 1: 40.0
- Group 2: 0.0
- Group 3: 0.0
- Group 4: 0.0

**Annual Discount Rate (%)**: 3%
**Illness Duration (Days)**: 4
**Disability Weight (Between 0-1)**: 0.202
The Output is weighted by the Population Distribution

Green Indicates that an intervention is very cost-effective (less than GDP/Capita), Yellow that an intervention is cost-effective (less than 3 times GDP/Capita), and Red that an intervention is not cost-effective.

Each sub-section gives the value where the intervention would be cost-effective.
Using the Graphs

**Graph 1:**
- Blue lines indicate cost-effectiveness thresholds.
- Points represent each group and those below the lines are cost-effective.
- **Group 1** and **Total** are marked.

**Graph 2:**
- Blue lines represent cost-effectiveness thresholds.
- Bars are the cost per DALY averted and falling below the lines indicate cost-effectiveness.
- Group 1, Group 2, Group 3, Group 4, Total.

**Graph 3:**
- Blue shaded regions indicate cost-effectiveness. Points represent each group.
- **Group 1** is marked.

**Graph 4:**
- Blue shaded regions indicate cost-effectiveness at increasing costs of vaccination.
- **Case Fatality Ratio (%)**

*The Incidence and Case Fatality Ratio of disease are shown. Areas shaded blue are cost or very cost-effective.*

*The incidence and Case Fatality Ratio of disease are shown. Areas above and to the right indicate combinations that are cost effective at costs per fully vaccinated individual $1-10.*
Each Group is represented by a ‘dot’ in this plot. The graph shows the number of DALYs averted in each Group on the x-axis and the Net Vaccination Cost for each Group on the y-axis. The Cost-Effectiveness Ratio then is the Cost/DALYs. If the dot is below the dark blue line, the Ratio is Cost-Effective (less than 3 x GDP/Capita) and if the dot is below the light blue line, the Ratio is Very Cost-Effective (less than GDP/Capita).
The Cost per DALY Averted is the Cost-Effectiveness Ratio. This graph shows the Ratio for each group, independently, and for the weighted average ‘Overall’ Cost-Effectiveness Ratio. If the bars are below the dark blue line, the Ratio is Cost-Effective (less than 3 x GDP/Capita) and if the bars are below the light blue line, the Ratio is Very Cost-Effective (less than GDP/Capita).
Like Figures 1 & 2, this graph has two blue lines representing the cut-off thresholds for Cost-Effectiveness. Here, the lines and the dots for each Group are plotted for the values of the disease Incidence and Case Fatality Ratio. If the dots are above the blue lines, the combination of Incidence and CFR in those groups is either Cost-Effective (dark blue line) or Very Cost-Effective (light blue line).
Figure 4 is a contour plot of decreasing cost per fully vaccinated individual. Combinations of incidence and case fatality ratio that fall in varying shades of blue indicate the lowest disease burden where vaccination would be cost-effective. The gray area is not cost-effective at $2 or greater.
EXAMPLE ANALYSIS: CHOLERA IN VIBRIOLAND
An Example Analysis using VICE

• Oral cholera vaccine introduction in the hypothetical country Vibrioland
  – Is oral cholera vaccine cost-effective in Vibrioland?
  – How can targeted vaccination strategies improve the economic and health efficiency?
  – In what way can a cost-effectiveness analysis help evaluate vaccination campaign decisions?
Vibrioland Background Information

- Have enough oral cholera vaccine for 250,000 people
- The total purchasing and delivery cost of the vaccine is $5/person
- The national cholera incidence in Vibrioland is 0.5/1,000/year, and a 2.1% case fatality ratio
- The estimated public Cost of Illness is $25/case
- Life Expectancy at age of infection is 40 years on average
- The Gross Domestic Product per Capita in Vibrioland is $1000
Vibrioland has a low burden of cholera, on average and vaccinating the population non-selectively is not cost-effective.

If vaccination were targeted to populations with a greater burden of disease incidence and mortality, however, it may be cost-effective.
Targeting a High-Risk Population

As vaccination at the national level is not cost-effective, we may reconsider the strategy to target a high-risk population:

• Maximizes benefit, may be desirable for health equity reasons

• “High-risk” district has endemic transmission:
  – Cholera incidence = 7.5/1000/year
  – Case fatality = 2.1%
<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select Country Below:</td>
<td>Total Cost: $1,250,000.00</td>
</tr>
<tr>
<td>None / Other</td>
<td>Cost Averted: $91,406.25</td>
</tr>
<tr>
<td></td>
<td>Net Cost: $1,158,593.75</td>
</tr>
<tr>
<td>People Fully Vaccinated: 250,000</td>
<td>Non-Fatal Cases Averted: 3,579</td>
</tr>
<tr>
<td>Vaccine Purchasing Cost ($) $3.70</td>
<td>Deaths Averted: 77</td>
</tr>
<tr>
<td>Vaccine Delivery Cost ($) $1.30</td>
<td>Total Cases Averted: 3,656</td>
</tr>
<tr>
<td>Duration of Immunity (Years) 3</td>
<td>No. Vaccinated/Death Averted: 3,256</td>
</tr>
<tr>
<td>Cost of Illness ($) $25.00</td>
<td>No. Vaccinated/Case Averted: 68</td>
</tr>
<tr>
<td>Gross Domestic Product/Capita $1,000.00</td>
<td>DALYs Averted: 1,745</td>
</tr>
<tr>
<td>Population Distribution (% of Total)</td>
<td></td>
</tr>
<tr>
<td>Vibrioland 0%</td>
<td>Cost per Case Averted: $316.88</td>
</tr>
<tr>
<td>High-Risk District 100%</td>
<td>Cost per DALY Averted: $664.10</td>
</tr>
</tbody>
</table>

As predicted, this High-Risk District of Vibrioland would be cost-effective to vaccinate.

<table>
<thead>
<tr>
<th>Output</th>
<th>Cost-Effectiveness Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Vaccine Cost of Purchase &amp; Delivery ($)</td>
<td>Total Vaccine Cost of Purchase &amp; Delivery ($)</td>
</tr>
<tr>
<td>Cost Effective: $21.30</td>
<td>Very Cost Effective: $7.34</td>
</tr>
<tr>
<td>Vaccine Efficacy (%)</td>
<td>Vaccine Efficacy (%)</td>
</tr>
<tr>
<td>Cost Effective: 15.3%</td>
<td>Very Cost Effective: 39.0%</td>
</tr>
<tr>
<td>Incidence (per 1,000/year)</td>
<td>Incidence (per 1,000/year)</td>
</tr>
<tr>
<td>Cost Effective: 1.76</td>
<td>Very Cost Effective: 5.11</td>
</tr>
<tr>
<td>Case Fatality Ratio (%)</td>
<td>Case Fatality Ratio (%)</td>
</tr>
<tr>
<td>Cost Effective: 0.46%</td>
<td>Very Cost Effective: 1.39%</td>
</tr>
</tbody>
</table>

**Numbers rounded**
Age-specific targeting

- Recommended, feasible to target children 1-14 years, 5-14 years (school aged)
- High-risk, cholera endemic region
- **Toddlers:** Children 1-4 YO (15% of Population)
  - Incidence = 8/1000/year
  - Vaccine efficacy lower (40%)
- **School-aged:** Children 5-14 (30% of Population)
  - Incidence = 6/1000/year
- **Adults:** 15 years and older (55% of Population)
  - Incidence = 1/1000/year
- Case fatality = 2.1%
It is cost-effective to vaccinate toddlers and school children in this scenario but not adults or Vibrioland in general because the corresponding dots are below the dark blue line (left) and because the corresponding bars are below the dark blue line (right) but each group differs in the cost per DALY averted.
Summary

• The Vaccine Introduction Cost-Effectiveness calculator may be a useful tool for vaccine decision making
• VICE is suitable for homogeneous or heterogeneous populations
• DALYs Averted are very sensitive to changes in disease incidence and mortality
• There is no “right” answer to cost-effectiveness analyses; they are highly context-specific.
Additional Resources

Methods and Calculations based on:


World Health Organization Choosing Interventions that are Cost-Effective (CHOICE) Guide to Cost-Effectiveness Analyses:

• **WHO CHOICE**: [http://www.who.int/choice/en/](http://www.who.int/choice/en/)

Contact Information

The VICE model is a work in progress. For any questions or comments on how to improve the design or function of the calculator, please contact:

Christopher Troeger  
Center for Statistics and Quantitative Infectious Diseases  
Fred Hutchinson Cancer Research Center  
Seattle, WA, USA  
ctroeger@fhcrc.org