

**Cost Analysis of Malaria Elimination in  
Hainan and Jiangsu Provinces, China and in Swaziland**

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**A Background Paper  
for Chapter 4: Financing Elimination**

from

*Shrinking the Malaria Map: A Prospectus on Malaria Elimination*

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## **Introduction**

This background paper provides further technical detail regarding the analyses of costs of malaria elimination presented in Chapter 4 of *Shrinking the Malaria Map: A Prospectus on Malaria Elimination*. It is intended for the reader interested in data and assumptions underlying these analyses, as well as the potential implications for findings of selected uncertainties in analysis methods.

The background paper is organized mainly as three case studies – for Jiangsu and Hainan provinces in China, and for Swaziland. We do not repeat the material in Chapter 4, including context, conceptual discussion, literature review, methods, and findings. Thus, the background paper should be read in conjunction with the chapter, if the reader desires the full consideration of financing and cost issues.

We also report some health and economic indices of program performance not included in Chapter 4. In particular, we report cases and disability-adjusted life years (DALYs) averted and, when appropriate, cost per DALY averted.

We anticipate that subsequent versions of this background paper will include case studies for other locations. In particular, we are currently collecting and analyzing cost data from Mauritius and the Philippines.

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### **Cost and Cost-effectiveness analysis applied to malaria elimination**

*Cost-effectiveness analysis* compares the net cost of health interventions to the health benefit achieved. The *net cost* represents the cost of implementation, minus any savings accruing due to averted disease and associated averted costs of providing health care. Savings may also occur due to diminished risks of disease and associated lower public health control costs (e.g., prevention).

Health benefits are typically measured first in natural clinical units appropriate to the disease, such as disease-specific morbidity and deaths averted. The benefits are then translated into a standard metric that permits summing across diverse clinical events and comparison across diseases. This metric is Disability Adjusted Life Years (DALYs). The DALY combines the concepts of lost life years due to premature death and reduced productivity due to disability. Since DALYs represent the loss of health status, they are to be averted.

While prevention and treatment costs in highly endemic areas are generally very cost-effective, elimination presents different cost-effectiveness issues. First, elimination is contemplated only in situations with few malaria cases to avert. Thus, new strategies are likely to yield relatively few DALYs averted, compared with the same strategies in high-burden settings. Secondly, elimination offers the prospect of significant savings in future malaria control costs. Successful elimination would reduce treatment costs (with only imported cases requiring treatment). Elimination would also potentially lead to a large reduction in the costs of prevention, as intervention measures are confined to restricted geographic areas such as entry ports and border zones. In some cases, therefore, pursuing elimination may “pay for itself”.

We conducted preliminary cost and cost-effectiveness analyses of planned malaria elimination in Jiangsu and Hainan provinces, China, and in Swaziland.

Our goal was to explore long-term costs versus savings and, if there is a positive net cost to elimination, the cost per DALY averted. This “longitudinal analysis” explores the costs of elimination versus sustained control over 20 years, accounting for future savings due to reduced malaria control costs. Importantly, this analysis provides the inputs needed for the longer (100-year) analysis of internal rates of return reported in Chapter 4, however takes a more conservative approach to predicting future trends, which can be very uncertain after 20 years. This analysis also includes an examination of the implications of imported malaria cases for potential reductions in control costs.

### **China: Jiangsu & Hainan**

#### ***Methods***

We obtained data on current control and anticipated incremental elimination costs from Jiangsu and Hainan health officials, based on Ministry of Health expenditures and budgets (national, provincial, and local), as well as Global Fund proposals. The current and projected elimination costs are divided functionally, allowing us to understand spending in four broad categories that we believe will respond differently to successful elimination efforts: surveillance, treatment, prevention, and program management.

Jiangsu, a central province, reported 940 malaria cases in 2007 in a population of 73,000,000 (0.129 per 10,000), of which 100% are *P. vivax*. Under-reporting is estimated at 4.5-fold, suggesting 4,230 actual cases per year. These are internal cases, excluding border cases (which are discussed below). Jiangsu is aiming for elimination by year 8. This goal is reflected in our longitudinal analysis.

In Hainan, an island province, there were 3,417 reported malaria cases in 2007 in a population of 8.3 million (4.1 per 10,000), with an estimated distribution of 10% *P. falciparum* and 90% *P. vivax*. There have been no malaria deaths for several years. Adjusting for under-reporting based on survey findings (7 fold) leads to estimates of 23,919 cases per year (2,392 *P. falciparum* and 21,527 *P. vivax*). The province is aiming for *P. falciparum* elimination and *P. vivax* reduction to extremely low levels by year 5, and *P. vivax* elimination by year 8.

In this longitudinal analysis, we tried two approaches to estimate savings in malaria control costs. First, we relied on the expert opinion of officials we interviewed, regarding the scale of efforts required to achieve sustained control in the long term. Second, we used an algorithmic approach. We assumed that malaria control cost savings (e.g., decreased need for prevention) reflect the reduction in cases, and that different types of costs may be differentially sensitive to these case reductions. For example, a 90% reduction in cases might correspond to a 90% reduction in treatment costs. The model allowed us to explore the effect on results of different quantitative values for assumptions. The two longitudinal analysis methods yield very similar results for Hainan, but different results for Jiangsu.

Imported malaria cases are important to overall costs and to potential savings. To explore the effect of imported cases, we incorporated two parameters in the analysis. First, we specified a zero to one scale that represents the severity of the border problem. In this scale, 0 designates no border cases and 1 designates a very severe border problem. Roughly, the score reflects the proportion of current cases due to border-crossing. Second, we specify how the border problem affects the sensitivity of control costs to the reduction in cases. For example, a value of 0.3 for surveillance means that a border problem of severity = 1 results in an added 30% surveillance cost (as compared with the start of the elimination phase); border problems of lesser severity lead to proportionally lower additions to costs. The model allows exploring the effect on results of different input values.

Finally, we represent the longitudinal results with the internal rate of return (IRR). The IRR quantifies the extent to which initial spending on elimination yields net financial returns through decreased control costs later in the 20 year time frame. The IRR is defined as the discount rate which generates a net present value of zero for the total of annual differences in cost between elimination and ongoing control.

## **Results**

This “over time” (longitudinal) analysis explores how elimination might affect total malaria control costs over 20 years. We compare current ongoing costs (i.e., ongoing sustained control) with the added costs and subsequent savings from elimination. This presents an inclusive, and thus likely more realistic, assessment of the net costs of elimination than a shorter term analysis.

For Jiangsu, the longitudinal result appears attractive. The reason is that the anticipated incremental cost of elimination is small in relation to current control costs. Jiangsu officials estimate \$6.5 million in annual incremental elimination costs, as compared with \$9.1 million in annual sustained control costs (i.e., a 71% increase).

After year 5, we assume a sensitivity of each cost category to decrease. For example, with no border effects, we assume that treatment costs are 100% sensitive (1.0) to case counts, but that prevention is fairly sensitive to case counts after 5 years once elimination is nearly achieved (0.8).

The extent of importation risk affects this sensitivity. If migrants largely originate from non-endemic areas, as in Hainan, we would assume that importation risk is low at 0.05. This results, for example, in a final sensitivity to drop in cases of 0.99 for treatment and 0.785 for prevention after 5 years. For Jiangsu, with a greater importation risk, we use a value of 0.25 (explored below), so the final sensitivities are lower.

The result for Jiangsu is presented in Figure 4.2. The undiscounted cumulative costs for elimination are \$161 million over 20 years, versus \$182 million for sustained control. The undiscounted cost lines cross at 14 years. The internal rate of return is 6.7%; this is the annual return on investment, which quantifies the financial yield of the initial outlay for elimination. No cost-effectiveness ratio is needed when programs yield net savings. If control costs following elimination are \$4 million, as discussed by Jiangsu officials (lower than our algorithm-based estimate of \$6.2 million), then the lines cross at 9.5 years, with an IRR of 13.9% (Figure 4.3).

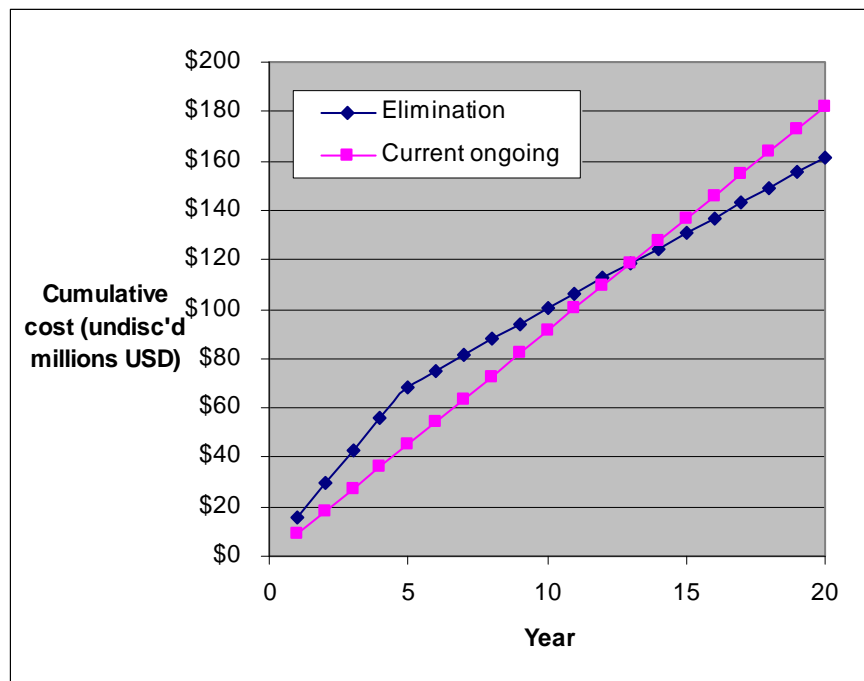


Figure 4.2. Potential costs over time, elimination vs. ongoing current sustained control, for Jiangsu, China, algorithmic approach.

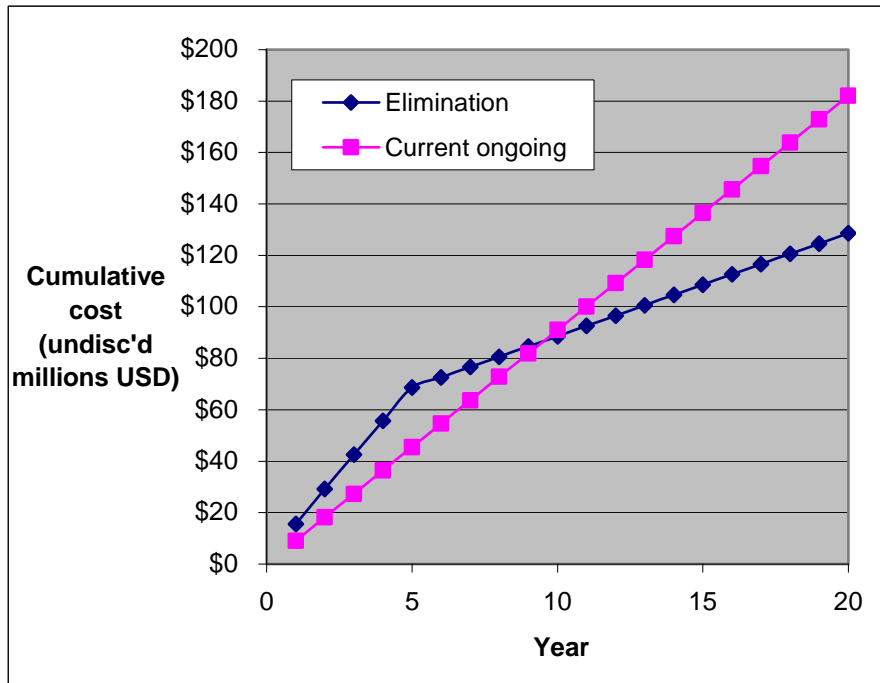


Figure 4.3. Potential costs over time, elimination vs. ongoing current sustained control, for Jiangsu, China, based on cost projections from health officials.

The scale of the border problem affects the internal rate of return for Jiangsu. If we increase the border problem scale from 0.25 to 0.4, based on 40% of current cases being imported, the lines cross at 18 years, with an IRR of 3.4%. If we decrease the border problem scale from 0.25 to 0.05, based on a sharp reduction in imported cases, the lines cross at 11 years, with an IRR of 10.5%. These findings suggest that spending money on malaria control in isolation – limited to national boundaries – is less cost-effective than providing funds to neighbors to enable success in their malaria elimination efforts. We have not formally analyzed this possibility.

For Hainan, the initial annual cost for the "current" and "elimination" approaches derive from Ministry and Global Fund budgets. Current spending is \$2.9 million per year. The division into cost categories is based on local government budget and the Global Fund Round 5 application: treatment 10%, prevention 40%, surveillance 20%, and program management 30%. Incremental spending for elimination is \$6 million in the first year, for total spending of \$8.9 million overall in that year. In years 2-5, total spending drops from \$5.1 million annually to \$4.6 million annually. We assume, from the local government budget and Round 8 Global Fund application, the following distribution: treatment 5%, prevention 52%, surveillance 18%, and management 25%.

The longitudinal analysis compares current ongoing sustained control with an elimination strategy. Current ongoing costs in Hainan are \$2.9 million per year, or \$58 million undiscounted over 20 years. In the elimination strategy, both current costs and incremental elimination spending decrease in response to the reduced numbers of malaria cases (as described above). We assume that case load drops to 30% in year 2, 20% in year 3, 10% in year 4, 5% in years 5-7, and

0% thereafter (i.e., elimination). This yields annual costs after elimination similar to local officials' assessments.

Figure 4.4 presents the predicted cumulative costs (undiscounted) with the two strategies in Hainan. As would be expected, elimination costs are higher than current ongoing costs initially. This difference grows during the elimination period, with roughly stable annual spending. With the later reduction in case load-sensitive costs, the difference drops slowly. However, the annual difference in spending between post-elimination and the current ongoing control strategy is small, and the higher cumulative cost of the elimination strategy persists through 20 years.

The difference in results for Hainan as compared with Chapter 4 is instructive. In Chapter 4, we reported that over 100 years, net savings are expected in Hainan, with an internal rate of return of 3%. Here, we report that over 20 years, given the same data on annual control costs, there is a net cost. This illustrates the importance of a long perspective: the twenty year time horizon misses slowly accumulating effects. However, a 20 year perspective may be less prone to errors since predicting far into the future makes potentially incorrect assumptions about stability in malaria control technologies and options. Thus, there is a trade-off: more robust model assumptions, vs. capturing very delayed effects that would accrue if present conditions persist.

If we assume that current control costs were higher, for example, \$3.5 million per year instead of \$2.9 million the long-term analysis would show small net savings over 20 years (Figure 4.5), with an IRR of 3.6%. That is, if sustained control costs rose over time, as they would do with efforts to further decrease disease burden, they could get to a point where it would be cost saving to go for elimination. Lower costs of elimination and preventing re-introduction would produce similar patterns.

Although it appears that Hainan may not realize net savings with elimination in 20 years, the partial savings from anticipated reduction in future control costs has a favorable effect on the cost-effectiveness ratio. Assuming a 3% annual discount rate, recommended for cost-effectiveness analyses, then over 20 years elimination costs \$8.49 million more than ongoing current control. The added expenditure results in 338,824 malaria cases averted (discounted). This translates to \$25 per case averted, or \$1,829 per DALY averted.

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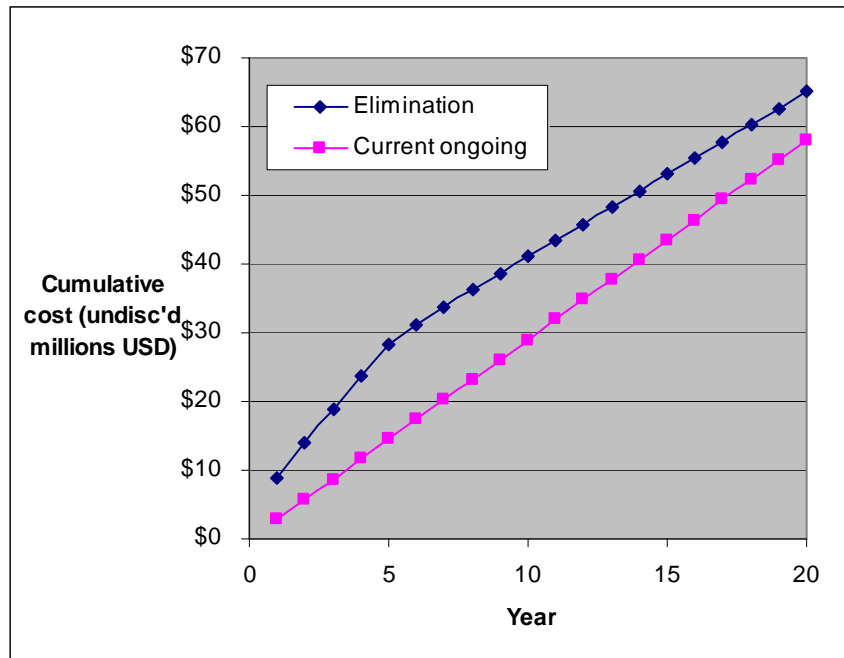


Figure 4.4. Potential costs over time, elimination vs. ongoing current sustained control, for Hainan, China.

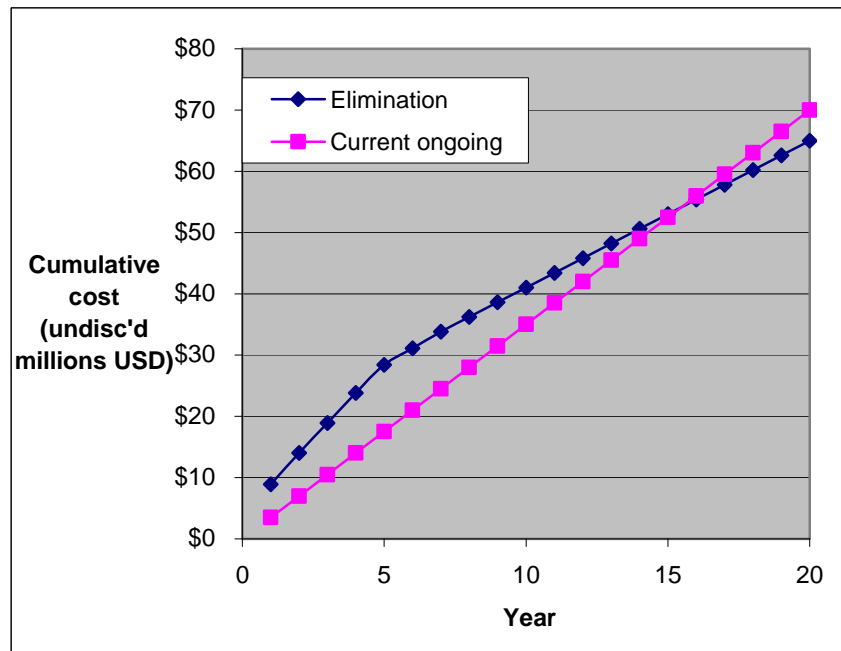


Figure 4.5. Potential costs over time, elimination vs. ongoing current sustained control, for Hainan, China, with higher current control costs (\$3.5 million instead of \$2.9 million).

## **Swaziland**

### **Method**

For Swaziland, we compared recent spending patterns for malaria control with budgeted spending for elimination and potential long-term spending to maintain malaria-free status.

Current annual government spending is \$400,000, increasing at 10% per year. In addition, for the last 5 years Swaziland has received \$1.4 million from a Round 2 grant of the Global Fund, representing \$280,000 per year. Thus we assume that annual spending to maintain control is \$680,000 (ignoring the rise with inflation).

The detailed budget for a pending Global Fund Round 8 malaria award, to achieve elimination, totals to \$12 million over five years (average \$2.4 million per year). This includes, in round numbers:

- *Vector control (mainly bed nets)*: \$1 million per year in years 1 and 2, then \$0 in year 3, and \$1.2 million per year in years 4 and 5. The pattern represents two cycles of bed net purchases.
- *Surveillance*: \$400,000 per year.
- *Case management*: \$250,000 - \$750,000 per year, with the variation due to repeated rounds of training and microscope purchase.
- *IEC*: rising from \$300,000 to \$400,000 per year over the five years.
- *Grant management*: \$100,000 per year.

With elimination, we project significant reductions in annual costs after five years due to fewer and more geographically constrained (predominantly imported) cases. Specifically we assume that:

- Government spending decreases to \$200,000 per year (50% drop)
- The Round 2 \$280,000 annual spending is no longer needed.
- Thus, annual savings in ongoing control costs = \$480,000.
- The type of activity and spending funded by Round 8 will decrease from \$2.4 million per year in the first five years (i.e., during Round 8) to \$1.25 million per year after five years:
  - Vector control: \$400,000 per year (55% drop from first five years)
  - Surveillance: \$400,000 per year (equal to first five years)
  - Case management: \$200,000 per year (57% drop)
  - IEC: \$200,000 per year (50% drop)
  - Management: \$50,000 per year (50% drop)

Reported malaria cases were 6523 in 2007, including 13 deaths. Local public health experts believe that there is significant over-reporting, due to clinical diagnosis, however there are no fully representative data to quantify this. In July 2008, a local study on severe and complicated malaria (i.e., all malaria cases admitted and treated at hospitals and health centers) found that 77% of suspected malaria cases were positive on smear. Extrapolating to reported cases, this suggests 5022 actual malaria cases per year, including 11 fatal.

We calculated the cost per malaria case and DALY averted, for each year after elimination is achieved. This provides a lower bound estimate of cost per adverse health event, because it ignores the higher elimination costs during the first five years.

### **Results**

The net increase in annual spending following elimination, as compared with current control costs, is \$570,000. This represents Global Fund Round 8 spending adjusted for projected reductions after five years (i.e., \$1.250 million), *minus* offsetting savings from reductions in ongoing control (i.e., \$680,000).

We do not provide a graph of current ongoing vs. Elimination costs over 20 years. If we did, it would show diverging lines, since there is a net increase in annual spending following elimination.

If the estimated 5022 malaria cases drop to zero, that means that the annual cost per malaria case averted is \$113 (i.e., \$570,000 / 5022).

The estimated DALYs averted is 290. This represents the sum of 0.014 DALYs per 5011 non-fatal case, and 20 DALYs each for the 11 deaths. Thus, the cost per DALY averted is \$1966.

This calculation does not consider important positive externalities such as potentially improved health care worker training or increased tourism and investment.