An Investment Case for Eliminating Malaria in the Asia Pacific Region

wellcome trust MORU Tropical Health Network

UNIVERSITY OF OXFORD

APLMA ASIA PACIFIC LEADERS MALARIA ALLIANCE

UCSF Global Health Sciences
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REPORT

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Asian Development Bank
Passengers at the Yangon Myanmar Railway Station in Yangon, Myanmar (Burma)

The **Malaria Elimination Initiative (MEI)** at the University of California San Francisco (UCSF) Global Health Group believes a malaria-free world is possible within a generation. As a forward-thinking partner to malaria-eliminating countries and regions, the MEI generates evidence, develops new tools and approaches, documents and disseminates elimination experiences, and builds consensus to shrink the malaria map. With support from the MEI's highly-skilled team, countries around the world are actively working to eliminate malaria – a goal that nearly 30 countries will achieve by 2020.

shrinkingthemalariamap.org

Contents

Key terms and acronyms

ABC	ASEAN Business Club
ADB	Asian Development Bank
APLMA	Asia Pacific Leaders Malaria Alliance
ASEAN	Association of Southeast Asian Nations
GDP	Gross domestic product
Global Fund	Global Fund to Fight AIDS, Tuberculosis and Malaria
GMS	Greater Mekong Subregion
IMF	International Monetary Fund
IP	Inpatient
IRS	Indoor residual spraying
LIC	Low-income country
LLIN	Long-lasting insecticidal net
LMIC	Lower-middle-income country
MBI	Mekong Business Initiative
MDA	Mass drug administration
MDB	Multilateral development bank
MOH	Ministry of Health
NMCP	National malaria control program
NSP	National strategic plan
OECD	Organization for Economic Cooperation and Development
OOP	Out-of-pocket
OP	Outpatient
PAR	Population at risk
PPP	Purchasing Power Parity
POR	Prevention of reintroduction
RDT	Rapid diagnostic test
ROI	Return on investment
STC	Sustainability, transition, and co-financing
UHC	Universal health care
UMIC	Upper-middle-income country
USD	United States dollar
VLY	Value of additional life year
WHO	World Health Organization

Executive Summary

The Asia Pacific region had made significant progress against malaria, reducing cases and deaths by more than 50% between 2010 and 2015. Multiple factors have contributed to these reductions including the unwavering political and financial commitment of governments, donors, and partners. However, the region continues to face a high burden of malaria, and gains made against the disease are fragile, threatened by declining donor support, budget deficits, and persistent health system challenges, particularly the risk of antimalarial drug resistance emerging from the Greater Mekong Subregion. To address these challenges, leaders in the region have committed to a goal of malaria elimination by 2030, endorsing a detailed plan to accelerate progress as outlined in the Asia Pacific Leaders Malaria Alliance (APLMA) Malaria Elimination Roadmap. Achieving this will require an intensification of efforts accompanied by a plan for sustainable financing for the region.

The Malaria Elimination Initiative at the University of California, San Francisco Global Health Group and APLMA have partnered to develop an investment case to estimate the cost of malaria elimination in the Asia Pacific region and to generate economic evidence that highlights the benefits of malaria elimination. A mathematical transmission model was developed to project rates of decline to elimination by at least 2030 and determine the associated costs of the interventions that would need to be undertaken to reach elimination on or before 2030.

The study estimates that by using a variety of aggressive interventions, all 22 countries in the Asia Pacific region can achieve elimination of *Plasmodium falciparum* and *Plasmodium vivax* malaria at different times, up to two years before the regional 2030 target at a median cost of USD 29.02 billion (range: 23.7-36.2 billion) between 2017-2030. Approximately 80% of the cost will be incurred in South Asia. The People's Republic of China and Republic of Korea are the only countries predicted to achieve elimination without scaling up current interventions. Sri Lanka already achieved malaria-free certification by WHO in 2016. Elimination is possible in Cambodia, Democratic People's Republic of Korea (DPRK), India, Lao People's Democratic Republic, Myanmar, Solomon Islands, and Thailand by 2030 using new tools and technologies. Targeting of interventions to only 70% of the population at risk could reduce the total cost to USD 22.49 billion, a reduction of nearly 25%.

Interrupting local transmission can save over 400,000 lives (range: 100,000-1.33 million) and avert 123 million malaria cases (range: 62.4-769 million), translating to benefits of USD 90 billion (range: USD 30-350 billion). Discontinuing vector control interventions and reducing treatment coverage rates to 50% will reverse the gains made, resulting in an additional 845 million cases, 3.5 million deaths, and excess costs of USD 7 billion. Malaria elimination in the Asia Pacific region has a healthy return on investment of 6:1 by generating major cost savings to the health system and broader economic benefits through increased productivity and household prosperity. Despite this evidence, there remains a significant annual gap in funding of about USD 2.5 billion or almost 80% of the estimated cost of elimination between 2018-2020, emphasizing the need for continued resource mobilization activities to sustain the end-game.

This investment case provides compelling evidence for the benefits of continued prioritization of funding for malaria and can be used to develop an advocacy strategy for increased domestic and external funding for the region to reach its goal to be malaria-free by 2030.

Introduction

Background

Financing for malaria in the Asia Pacific region has increased to about USD 450 million in 2016 while simultaneously halving the regional malaria burden between 2000-2015. Nevertheless, almost two billion people in Asia Pacific remain at risk of malaria and continued financing is needed to sustain these gains. Between 2006-2010, the Asia Pacific region attracted between 12% and 21% of global malaria funding from the Global Fund to Fight AIDS, Tuberculosis and Malaria (Global Fund) (Zelman *et al*, 2015). However, there has been a steady decline in external financing for malaria, particularly for middle-income countries experiencing relatively lower malaria transmission rates.[a] Although government financing for malaria has increased in many countries in the last decade, the need for malaria control and elimination far exceeds the available resources. This is particularly important in the context of elimination where malaria is no longer perceived as a threat with countries simultaneously facing competing disease priorities. At the same time, the region has experienced unprecedented economic growth, providing unparalleled opportunities to reach and sustain resources for malaria elimination.

Despite this progress and opportunities for elimination, the gains made are fragile and investments could be lost if malaria resurges. With the growing threat of antimalarial drug resistance arising from the Greater Mekong Subregion (GMS) and the urgent need to contain its spread, the case for malaria elimination has never been stronger. However, in order to achieve a malaria-free Asia Pacific – a goal endorsed by leaders at the highest levels though the Asia Pacific Leaders Malaria Alliance (APLMA)[b] – financial resources will need to be sustained. Failure to maintain resources for malaria elimination has the potential to reverse the impressive gains made. Reduced funding or political commitment has historically been linked to 75 resurgences of malaria in 61 countries since the 1930s (Cohen *et al*., 2014). In the Asia Pacific region, APLMA estimated in 2015 that this could lead to over 200 million preventable malaria cases by 2030 and an additional 1.3 million deaths (APLMA, 2015c).

> "Malaria elimination is the interruption of local transmission of a specified malaria parasite species in a defined geographic area. Continued measures are required to prevent the re-establishment of transmission. Countries are situated at different points along the road to elimination. The rate of progress will depend on the strength of the national health system, the level of investment in malaria control and a number of other factors, including biological determinants; the environment; and the social, demographic, political and economic realities of a particular country" (WHO, 2016).

Malaria in the Asia Pacific

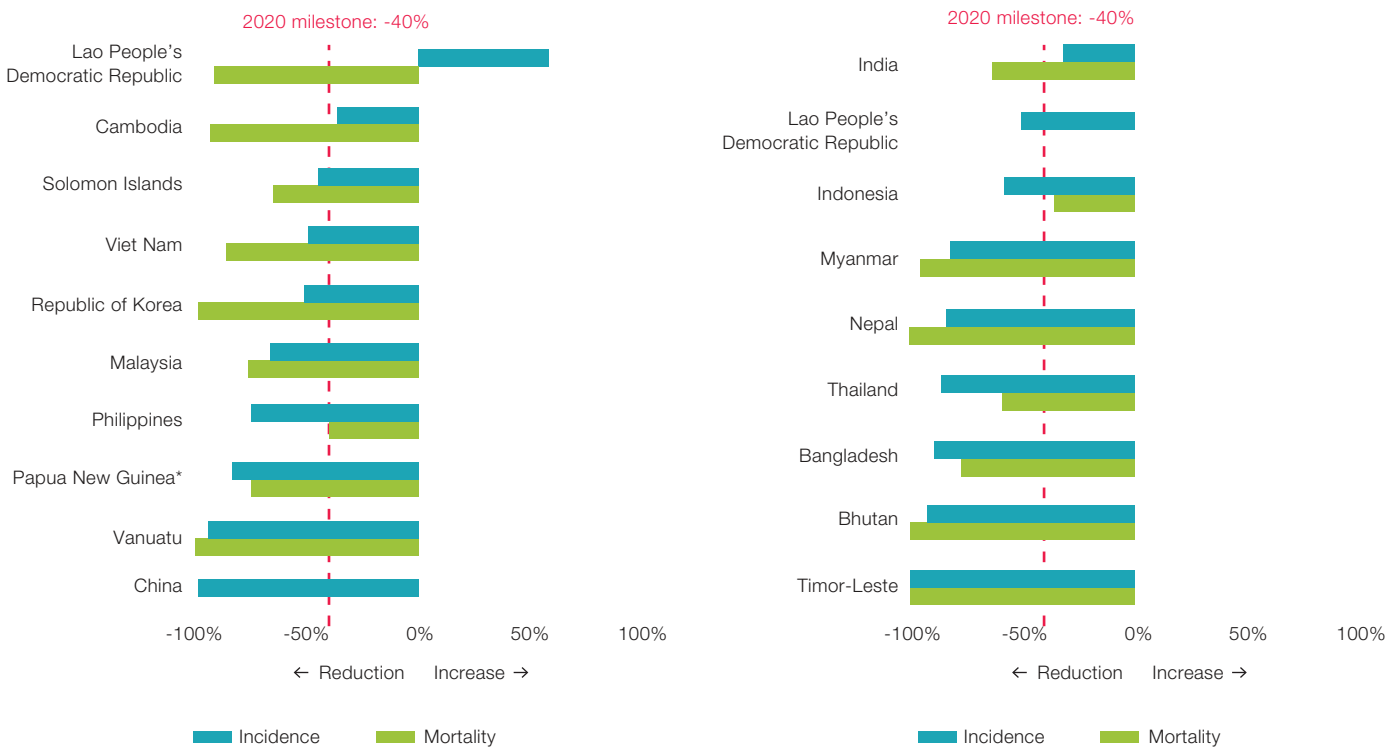
The Asia Pacific region has achieved significant gains against malaria over the last 15 years. Malaria cases and deaths have been reduced by more than 50% between 2010 and 2015 (Figure 1) in the region's 22 malaria-endemic countries.[c] Sri Lanka was declared malaria-free in 2016, becoming only the second country in Southeast Asia (after the Maldives) to successfully eliminate malaria. Apart from India, Indonesia, Myanmar, and Thailand, malaria-endemic countries in the Asia-Pacific reported decreases of malaria incidence of more than 75% since 2000. Cases and deaths declined by more than 50% between 2010 and 2015 in the majority of the countries in the region, surpassing the WHO milestone of a 40% reduction by 2015. In some cases, they have declined by almost 100%, with Bhutan, China, and Timor-Leste reporting less than 200 locally transmitted cases in 2015. Progress in driving down malaria is attributed to the scale-up of effective interventions to prevent, diagnose, and treat malaria, facilitated by strong political and financial support from governments and donors like the Global Fund to Fight AIDS, Tuberculosis and Malaria (the Global Fund).

a Low transmission refers to low-burden, pre-elimination, and elimination settings.

b At the 2013 East Asia Summit (EAS), the Asia Pacific Leaders Malaria Alliance (APLMA) was established to accelerate progress towards a reduction in malaria cases and deaths. In 2014 at the ninth EAS, the APLMA Co-Chairs (the Prime Ministers of Viet Nam and Australia) tabled a recommendation for the Asia Pacific region to become free of malaria by 2030. EAS Heads of Government agreed to the goal, and tasked APLMA Co- Chairs to present a plan to reach malaria elimination through a "Leaders Malaria Elimination Roadmap". The APLMA roadmap was presented to Heads of Government during the 10th EAS Meeting in 2015.

c The Asia Pacific region in this report encompasses the 22 malaria-endemic countries as defined by APLMA. Sri Lanka has since been declared as malaria free but still implements prevention of reintroduction activities. Countries include: Afghanistan, Bangladesh, Bhutan, Cambodia, Democratic People's Republic of Korea (DPRK), India, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Nepal, Pakistan, Papua New Guinea (PNG), People's republic of China, Philippines, Republic of Korea (ROK), Solomon Islands, Sri Lanka, Thailand, Timor Leste, Vanuatu and Vietnam.

Figure 1. Change in malaria incidence and mortality, 2010-2015



Source: WHO 2016. World Malaria Report

Nevertheless, malaria remains a major cause of death and illness in the region with an estimated 1.72 billion people at risk of the disease in 2015 (WHO, 2016a).

Approximately 260 million people live in high-transmission areas. In 2015, among the 21 countries in the region with ongoing malaria transmission or working towards prevention of reintroduction (POR), there were 6,345,208 presumed and confirmed cases of malaria according to the World Malaria Report (WHO, 2016a) of which 53% of cases were due to *Plasmodium falciparum (P. falciparum)* and 41% due to *Plasmodium vivax (P. vivax)* cases. The remaining infections may include *Plasmodium malariae*, *Plasmodium ovale*, and *Plasmodium knowlesi*. Of this total, 14,729 cases were reported to be imported. South Asia carries the highest burden of disease with India alone accounting for 49% of global *P. vivax* malaria cases in the Asia Pacific and 51% of global *P. vivax* malaria deaths in 2015 (WHO, 2016a). The numbers of confirmed cases by country and species are shown in Figure 2.

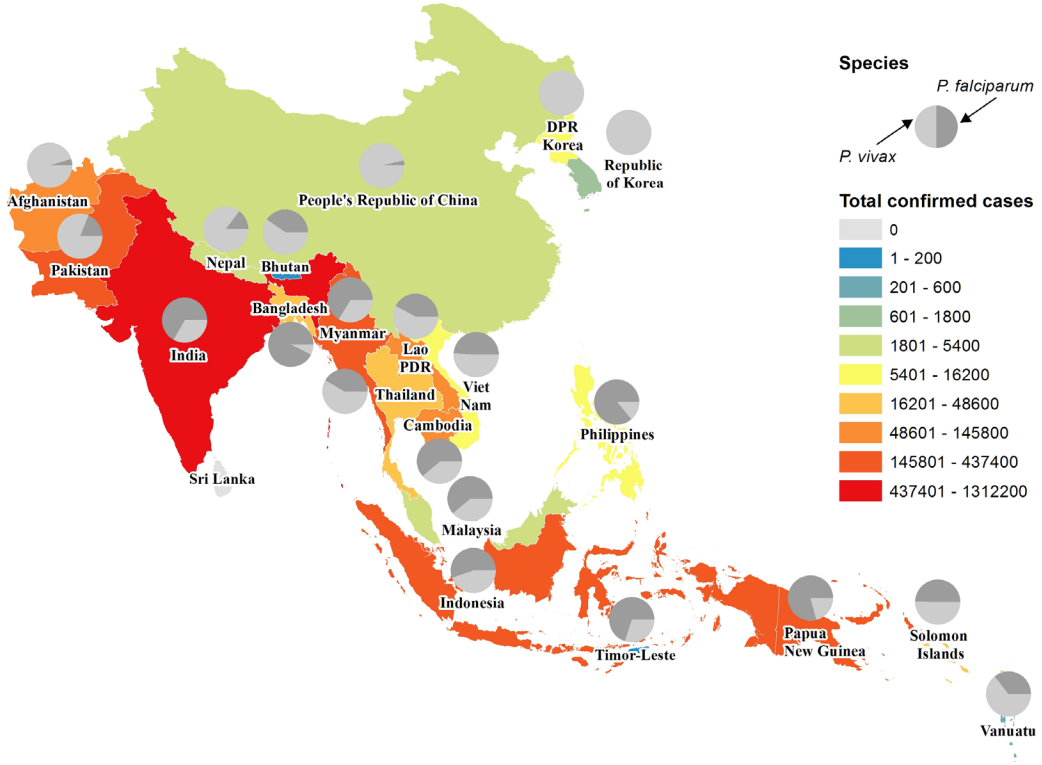
About 20 different Anopheles vectors have been implicated in malaria transmission in the Asia Pacific. Some of these vectors bite outdoors, between early evening to the early hours of the morning, and exhibit zoophilic biting—behaviors that require expanded vector control interventions beyond long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS) and improved targeting of high risk populations.

Table 1. Asia Pacific at a glance*

6,345,208	**Total reported cases of malaria (presumed and confirmed)**[a] (53% *P. falciparum*), 41% *P. vivax*, 6% other
20,289,440	**Total estimated cases of malaria**[b]
922	**Deaths from malaria**[a]
1.7 billion 327.5 million at high risk	**Population at risk**[a] (45% of total UN population estimate in 2015)
1.2 billion	**Population living in poverty**[c]
40%	**Share of global GDP generated**[d]
215.15	**Average total health expenditure per capita per year, 2014**[e] (current USD)
0.09	**Malaria financing per capita per year**[a] (current USD)

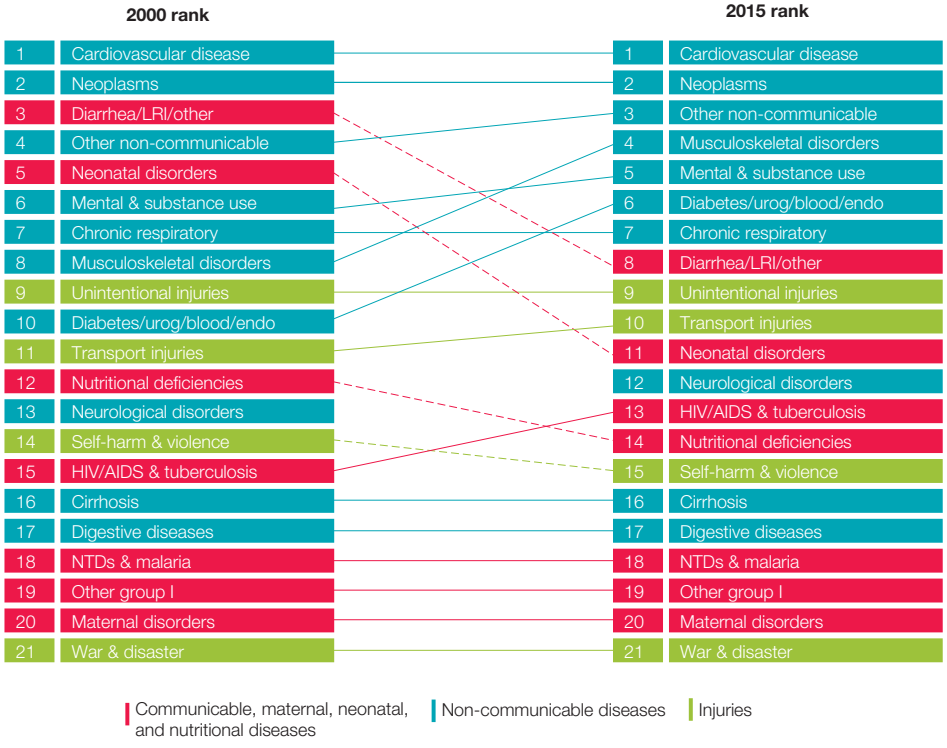
* Asia Pacific Region includes 22 malaria-endemic countries; data are from 2015 unless specified otherwise
[a] World Health Organization, 2016 World Malaria Report
[b] World Health Organization, based on estimated number of malaria cases identified in the private sector
[c] Below the poverty line of USD 3.10 a day (2011 purchasing power parity); Asian Development Bank
[d] 2011 purchasing power parity; Asian Development Bank
[e] World Health Organization, Global Health Expenditure Database

Figure 2. Confirmed P. falciparum and P. vivax malaria cases in Asia Pacific, 2015



Source: CE Mercado et al. *Malar J*, 2917;16:127

Figure 3. Leading causes of disability-adjusted life years lost in Southeast Asia, East Asia, and Oceania, 2000 and 2015*



*Both sexes, all ages, percent of total DALYs
Source: IHME Global Burden of Disease

According to the Global Burden of Disease study, malaria in the Asia Pacific was responsible for 0.22% of all deaths and 1.07% of all disability-adjusted life years (DALYs) lost in 2015 (IHME, 2017). Malaria, along with other neglected tropical diseases, was the 18th highest cause of DALYs lost in 2000 and 2015 in the region (Figure 3).

Financing for malaria in the Asia Pacific region

Economic transition of countries in the Asia Pacific Region

Asia Pacific economies have been growing by approximately 6% over the past five years, and although the International Monetary Fund (IMF) expects the region's growth to decelerate to 5.3% in 2016-2017, the Asia Pacific is still the world's fastest growing region (IMF, 2016). According to the Asian Development Bank (ADB), Asia and the Pacific generated two-fifths of global gross domestic product (GDP) in 2015 (2011 purchasing power parity [PPP]).

The Asia Pacific region's continued economic development presents both opportunities and challenges with regards to health and malaria elimination. While the growth in wealth has been unequally distributed both between and within countries, economic advancement has increased the fiscal space in many countries to invest in socio-economic development and health.

This strong economic growth has also led to changes in the way economies are classified by the World Bank. In 2001, the World Bank classified 14 countries in the region as low-income countries (LICs), 13 as lower-middle-income countries (LMICs), and only three as upper-middle-income countries (UMICs) (World Bank, 2017). In 2016, only three countries were classified as LIC, 21 as LMIC, and eight as UMIC. The income classification dictates countries' abilities to attract development financing, including grants and concessional loans from donors and multilateral development banks (MDBs). In the coming years, external donors like the Global Fund will increasingly focus on sustainability, transition, and co-financing (STC). The Global Fund's new STC policy emphasizes long-term sustainability as a key aspect of health financing and that all countries, regardless of their economic capacity and disease burden, should embed sustainability considerations within national strategies, program design, and implementation. This focus will be particularly relevant for UMICs and LMICs in the Asia Pacific, with moderate disease burdens, such as Malaysia, the Philippines, Sri Lanka, and Thailand. Figure 5 illustrates the projected growth of select economies in the region to 2020.

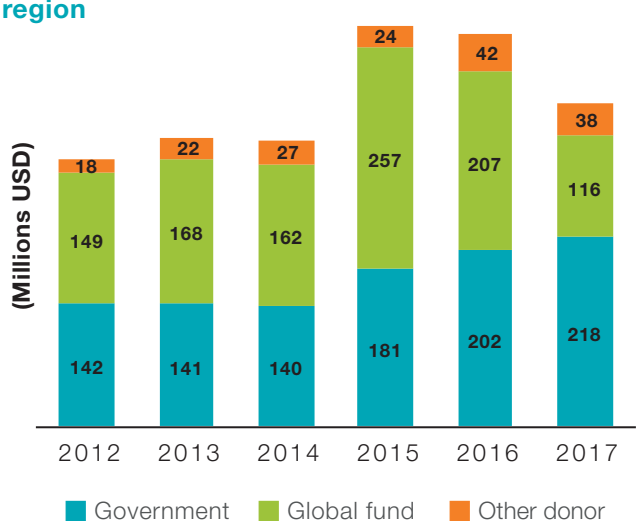
The supply of resources

The main sources of financing for malaria in Asia Pacific are domestic government resources and external financing from donors.

External financing contributions

Most national malaria control programs (NMCPs) in the region continue to be highly reliant on external financing, particularly from the Global Fund. As Figure 4 illustrates, almost 50% of the total funding for malaria in Asia Pacific

Figure 4. Financing for malaria in the Asia Pacific region



Source: Global Fund, Unpublished data

in 2016 was from the Global Fund. Other contributions are made by the US President's Malaria Initiative (PMI), the Bill & Melinda Gates Foundation, and the governments of Japan, Australia and the United Kingdom. This dependence on external financing is projected to continue in 2017 and beyond.

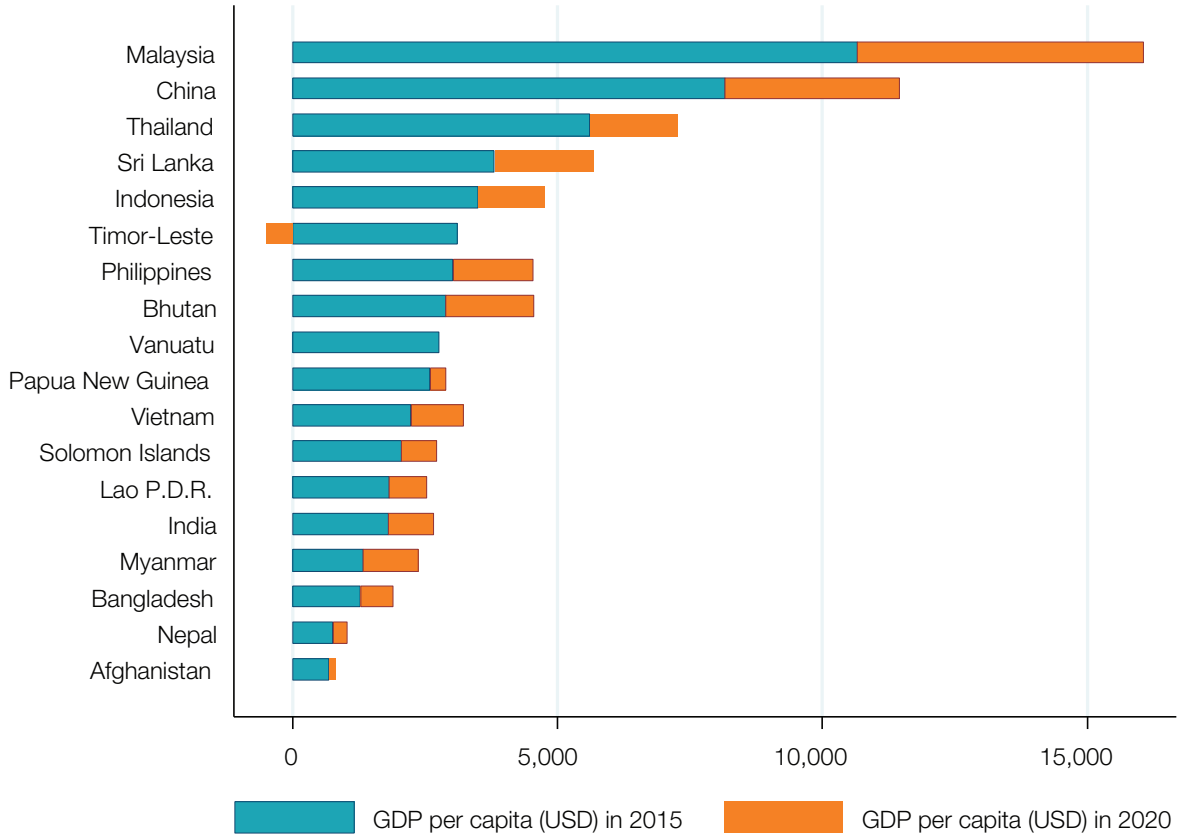
Government financing contributions

The 22 countries in the Asia Pacific region have collectively reported domestic financing levels of USD 267.6 million for malaria to the Global Fund in 2016 (Global Fund, 2017). The need, defined by the implementation of the national strategic plans (NSPs), is just over USD 800 million[d], signifying a gap of roughly USD 392.7 million. This amount mostly refers to funding directly available for vertical malaria control activities.

Government commitments for 2015-2017 have seen an overall 46% increase compared to 2012-2014 levels (Global Fund, 2017).[e] Nevertheless, there is still an estimated funding gap of about 50% of the total need, as estimated through expressions of need in NSPs for malaria. Regional health security and economic growth is at risk if countries in the region scale back aggressive operations because of declining levels of external funding, or due to

d It should be noted that the NSPs are not consistently costed for elimination
e Overall domestic spending on malaria stagnant between 2012 and 2014 due to decline of government spending in India with end of World Bank loan.

Figure 5. GDP per capita in 2015 and 2020 (projected) for select Asia Pacific countries



Source: Shretta R. 2015. Financing for malaria elimination. Presentation made at Wilton Park, Steyning, October 2015 (data from World Bank)

complacency and failure of governments to finance malaria interventions through domestic resources.

Asian economies spend a median of just over USD 730 per person per year on health, compared to USD 3,510 per person per year among high-income economies that are members of the Organization for Economic Cooperation and Development (OECD). This annual health spending amounts to just over 4.6% of the GDP on average in Asia compared to over 9.3% in OECD countries. In addition, the share of public spending in total health expenditures is much lower in Asia compared to OECD countries (48.1% vs 72.7%, respectively) (OECD, 2017). Per person at risk of malaria annualized expenditures vary considerably – with spending being higher in the Pacific than the rest of Asia.

The figures on domestic financing that are reported are estimated as it is difficult to obtain an exact picture of the domestic public resources allocated to malaria, as most of the resources available are drawn from general health system funding. It becomes even more complex to tease out the government expenditure on health and malaria as countries move towards more integrated health programs and sector-wide approaches that emphasize less specific earmarked funding for malaria.

In general, while UMICs like Thailand, Malaysia and China have more capacity to invest domestic resources, LMICs like Afghanistan, Cambodia and Lao PDR largely depend on external funding to deliver their national strategies.

The demand for resources

Costs of malaria control and elimination

The cost of malaria elimination in the Asia Pacific has been previously estimated by APLMA at USD 1 billion per year in the first five years of the implementation of its roadmap and just under USD 2 billion per year in subsequent phases, amounting to a total of USD 24.5 billion over 15

years. These costs were based mainly on transmission models whose exclusive focus was on *P. falciparum* malaria.[f] In the Asia Pacific region, *P. vivax* and other *Plasmodium* species are common, and the impact of malaria interventions such as long-lasting insecticide treated nets (LLINs) and indoor residual spraying (IRS) on those species differ from what has been observed for *P. falciparum*. Additionally, these models applied malaria transmission dynamics from Sub-Saharan African countries to other malaria-endemic countries to predict 90% reductions in current levels of malaria-related mortality and morbidity and not malaria elimination. Thus, the ability of the transmission model to simulate low or unstable levels of malaria transmission through to elimination is uncertain, which is problematic for many malaria-eliminating countries particularly in the Asia Pacific.

Other assessments of financial need in the Asia Pacific

In 2015, WHO estimated the cost of *P. falciparum* elimination in the GMS region to be USD 3.2-3.9 billion over 15 years (WHO, 2015c). However, these estimates were based on a cost model whose outputs were pre-determined by conditions such as the mix of interventions that countries might require to achieve elimination. The costs were not informed by predictions using epidemiological models that estimate the impact of interventions against the transmission of the disease. Using a transmission model, an estimate was made of the median cost to achieve malaria elimination in the GMS and prevent reintroduction by 2030 is USD 2.4 billion (range: USD 2.07-3.28 billion)(Shretta et al., 2017).

Costed National Malaria Strategic Plans (NSPs) for malaria in each of the 22 malaria-endemic countries can also be used as an indicator of financial need. However, financial requirements of NSPs are often not specifically calculated for elimination and often NSPs cover planned activities for shorter timeframes. Annex 1 illustrates the short-term needs and gaps, as expressed by countries in their NSPs.

Countries and partners need better estimates of the resources required to eliminate malaria in the long term, as well as evidence on the financial and economic benefits of investing in malaria elimination in order to advocate for more resources.

Objectives of the study

The objectives of this work were to:

- Estimate the cost to achieve malaria elimination in the Asia Pacific region by 2030;
- Generate an investment case for malaria by estimating the economic benefits of malaria elimination and POR; and
- Identify the funding gaps and explore the potential opportunities for generating financial resources for achieving malaria elimination goals.

f Asia Pacific Leaders Malaria Alliance. Malaria elimination roadmap. Manila, Philippines: APLMA; 2015.

Methodology

We used outputs from a mathematical transmission model to estimate the costs and benefits of malaria elimination. The model estimated the impact of several intervention scenarios on the transmission of *P. falciparum* and *P. vivax* malaria from 2016 to 2030 in each of the 22 countries. (See Annex 3 for full details on the methods.)

Elimination scenarios

The elimination scenarios modeled were categorized into two groups: "Accelerate" includes scaling up existing malaria control and elimination interventions while "Innovate" explores new and emerging interventions (Figure 6).

Elimination was defined as the first year in which less than one reported clinical case is achieved. Note that the model does not distinguish between indigenous and imported cases; hence, we estimated malaria elimination thresholds using a regression model of indigenous and imported cases from countries that have recently eliminated malaria. The scenario that allowed attainment of the elimination threshold was considered the elimination scenario. The scenarios used are described in detail in Table A3-2. The outputs of averted mortality and morbidity under the elimination scenarios were then used to estimate the cost, benefits, and returns on investment (ROIs).

Counterfactual scenarios

Two scenarios were used as the counterfactuals to malaria elimination: business as usual and reverse scenarios (see "Reverse" and "Continue" in Figure 6).

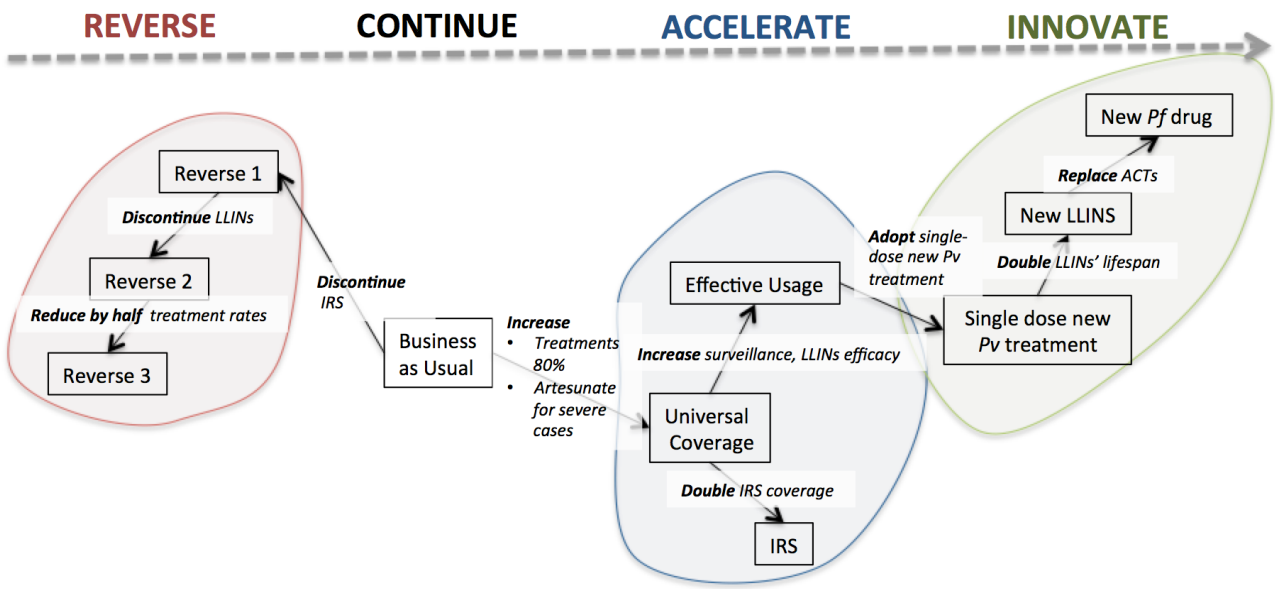
- **Business as usual**
  This scenario projects the malaria burden in 2016-2030 based on continuing the mix and scale of malaria interventions implemented in 2015.
- **Reverse scenario**
  This scenario projects the malaria burden in 2016-2030 assuming that LLIN distribution ceases and treatment rates fall by 50%.

Additional assumptions

We applied additional assumptions to simulate various possible outcomes. The first was around the occurrence of artemisinin resistance; across all scenarios, a baseline ACT treatment failure rate of 5% is applied in all countries from 2016-2030. Under the resistance assumption, the probability of treatment failure was kept constant at 5% through 2018 and increased to 30% between 2018 and 2025.

The second assumption concerns the use of mass drug administration (MDA). MDA has received increasing interest in the last decade with respect to its role in malaria

Figure 6. Scenarios used in the transmission model



elimination. MDA was simulated as five annual rounds of dihydroartemisinin-piperaquine at 50% coverage from 2018 onwards, starting four months before the peak of the malaria transmission season.

In a third set of simulations, LLIN scale-up was added to all the elimination scenarios in accordance with WHO guidelines for vector control if malaria elimination was not achieved by 2030. LLIN scale-up was defined as LLIN coverage of up to 80% coverage achieved through three-year distribution cycles from 2017 to 2026. These additional rates of decline were projected separately.

Population at risk

For all the scenarios, a declining population at risk (PAR) was assumed in the model. PAR values used to estimate costs in the model were obtained from the *World Malaria Report* and adjusted adjusted to reflect the decreases in incidence predicted from the implementation of elimination-focused interventions. Historical incidence and PAR data were analyzed statistically to infer a predicted change in PAR for a given change in incidence. This relationship was applied to the 2015 PAR data and updated every year until 2030 as interventions were applied in the modeled scenarios. This method has limitations, including a non-standardized definition of PAR.

In addition, we simulated the effect of improved targeting of malaria interventions on both costs and epidemiological outputs by reducing intervention coverage by 30% annually among the PAR for the elimination and counterfactual scenarios, with and without the resistance assumption.

Cost projections

We built a cost estimation model aligned with the outputs of the transmission model to estimate the total costs associated with implementing each of the scenarios above. Program costs included the costs of testing and treating uncomplicated or outpatient (OP) and severe or inpatient (IP) malaria cases; vector control (i.e., LLIN distribution and IRS); supply chains; surveillance through community health workers; information, education, communication; training; MDA; new treatments (e.g., tafenoquine for *P. vivax)*; and rollout of new LLINs. Unit costs for each activity were obtained using a combination of empirical data collected in various Asia Pacific countries by the MEI, literature reviews, and proxies when the previous options were unavailable.

The total cost of the elimination scenarios was used in this investment case. We calculated the costs to reach elimination separately for each country and then summed them to obtain the total cost for elimination in the Asia Pacific region. To calculate the incremental or additional costs of malaria elimination (which were used to calculate ROIs), we subtracted the estimated costs of the business as usual and reverse scenarios from the elimination scenario. All monetary figures are expressed in 2015 constant USD.

Economic benefits estimation

Using outputs from the model, we estimated the mortality and morbidity averted from malaria elimination by subtracting the estimated cases and deaths of the elimination scenario from the corresponding outputs of the business as usual and reverse scenarios. We then monetized these health benefits by looking at the averted cost to the health system, averted cost to individual households, and averted cost to society.

1. Cost averted to the health system includes costs associated with diagnosis and treatment costs of IPs and OPs;
2. Cost averted to the individual households is out-of-pocket (OOP) expenditures for seeking care; and
3. Cost averted to the society includes patients' lost productivity due to premature death and morbidity and caregivers' reduced economic output.

The same cost inputs used in the cost estimation were used for calculating the economic benefits. Unit costs for case management included costs for OP visits, diagnostic tests, and drug treatments for OP malaria cases, as well as hospital hotel costs and drug treatments for IP malaria cases. OOP expenditures were estimated by applying country-specific OOP expenditure per capita separately for OP and IP cases. We calculated productivity losses among patients and caretakers by multiplying an estimate of daily productivity by the number of days lost due to illness or care seeking.

We used the full-income approach to estimate the economic impact of lost productivity due to premature death from malaria. We multiplied the number of averted deaths for each country by the country-specific values of additional life years (VLYs) and life expectancies at age 40 among males and females, which was the assumed average age of death due to malaria. One VLY was estimated to be 2.2 times the GDP per capita for each of the countries in South East Asia and the Pacific and 2.8 times the GDP per capita for each of the countries in South Asia, as outlined in the *Lancet Commission on Investing in Health* (Jameson et al., 2013).

All costs and economic benefits were discounted at 3%.

Return on investment

The ROI was calculated by subtracting the incremental cost of elimination from the economic benefits, and dividing the resulting figure by the incremental cost of elimination. The ROI is interpreted as the economic return from every additional dollar spent on malaria elimination.

We performed the ROI analysis for 2016-2030 by comparing the elimination scenario with the business as usual and reverse scenarios under the stable and increasing resistance assumptions.

Uncertainty analysis

We performed a stochastic sensitivity analysis on the epidemiological and cost outputs of the malaria transmission model. The minimum, median, and maximum malaria cases and deaths predicted by the model for each scenario were used to calculate the minimum, median, and maximum economic benefits.

For the costs, we assigned an uncertainty interval of +/- 25% on the value of the input costs used. Three hundred random samples were drawn, which generated a range of costs. From the range of costs generated, we determined the minimum, maximum, median, mean, and other measures (e.g., percentiles). Similarly, a sensitivity analysis was conducted over a range of baseline estimated incidence values.

Limitations

There are considerable uncertainties associated with the estimates.

The transmission model was designed with a single homogeneous patch for the whole of each country. Thus spatial heterogeneity within each country was not modeled including malaria transmission and interventions. Targeting of interventions within a country may reduce the costs of elimination thus the estimated costs are likely to be an over-estimate. There is much uncertainty in the estimated malaria burden in each country with a resulting impact on the predicted costs of elimination. Population movement was not included in the model and this is is likely to have reduced the predicted costs.

We were unable to predict the impact that economic development and housing improvements may have on malaria transmission or how the costs of commodities or interventions may change at the global or national levels. Furthermore, the cost of new interventions such as new LLINs and new treatments such as tafenoquine were based on historical estimates of the cost of new tools when they were first adopted rather than actual costs. While we modeled for a declining PAR based on historical changes in PAR compared to changes in incidence, this method has limitations including a non-standardized definition of PAR.

In addition, the costs are highly dependent on the output of the transmission model, which was developed using national level data on incidence and intervention coverage. These estimates are subject to error, particularly in countries with heterogeneous transmission patterns. Furthermore, elimination often requires targeted interventions in areas of PAR, rather than ubiquitous coverage to an entire country. Without subnational estimates of incidence and coverage, targeted interventions are difficult to estimate and cost.

Gap analysis and opportunities for resource mobilization

Using available malaria financing data in the region (donor and domestic), between 2017-2020, we estimated the potential gap in financing assuming the total funding envelope would remain as projected. We also assessed potential opportunities for resource mobilization to fill financing gaps by mapping private sector investors and analyzing the domestic funding landscape.

RESULTS

Projected declines in transmission

The transmission model predicts that malaria elimination will be achieved by Asia Pacific countries using a variety of interventions. Figure 7 and Table 1 illustrate the predicted output of the transmission model under scenarios of increasing ACT treatment failure. Country level predictions are illustrated in Annex 5.

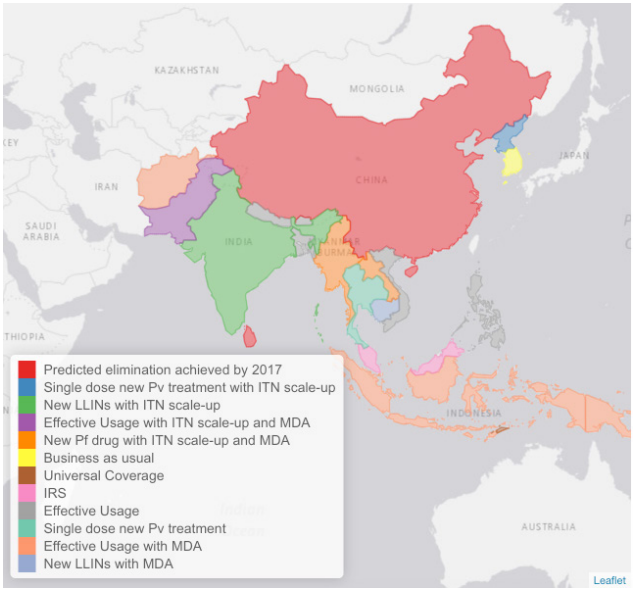
The minimum elimination scenario is defined as the scenario under which the country can achieve elimination on or before 2030 with the least amount of effort. The model, using median parameter values as model inputs, predictedpredicted that it is possible for all 22 countries to achieve elimination of *P. falciparum* and *P. vivax* by 2030. China, ROK, and Sri Lanka[g] are the only countries predicted to achieve elimination without scaling up current interventions. Elimination is possible in Cambodia, DPRK, India, Lao PDR, Myanmar, Solomon Islands, and Thailand by 2030 using new tools and technological innovation. Elimination is predicted to be possible by 2030 only through the addition of MDA in Afghanistan, Cambodia, Indonesia, Lao, Myanmar, Pakistan, PNG,

g Sri Lanka has achieved elimination and obtained WHO certification in 2016.

Table 1. Scenarios and predicted median elimination dates

Country	Minimum elimination scenario #	Minimum elimination scenario and interventions	MDA	ITN	Elimination date (median range)	National elimination goal
Afghanistan	77	Effective usage	Yes	Yes	2025 (2025,2027)	None
Bangladesh	67	Effective usage	No	No	2025 (2024,2029)	2035
Bhutan	67	Effective usage	No	No	2024 (2023, 2025)	2018
Cambodia	79	New LLINs	Yes	No	2023 (2022, 2030)	2025
China	Already eliminated by 2017	Business as usual (already eliminated by 2017)	No	No	2017	2020
DPRK	28	New *P. vivax* drug	No	Yes	2028 (2027, 2030)	2025
India	29	New LLINs	No	Yes	2028 (2026, 2030)	2030
Indonesia	77	Effective usage	Yes	No	2025 (2022,2028)	None
Lao PDR	40	New *P. falciparum* drug	Yes	Yes	2025 (2022,>2030)	2030
Malaysia	66	IRS	No	No No	2023 (2019, 2029)	2020
Myanmar	40	New *P. falciparum* drug	Yes	Yes	2025 (2024,>2030)	None
Nepal	67	Effective usage	No	No	2022 (2017, 2026)	2026
Pakistan	37	Effective usage	Yes	Yes	2022 (2021, 2030)	None
PNG	77	Effective usage	Yes	No	2025 (2025,2028)	2030
Philippines	67	Effective usage	No	No	2021 (2017,2023)	2030
ROK	61	Business as usual	No	No	2017 (2017,2019)	2017
Solomon Islands	79	New LLINs	Yes	No	2028(2026, 2029)	2030
Sri Lanka	already eliminated by 2017	Business as usual (already eliminated by 2017)	No	No	already eliminated in 2013	2012
Thailand	68	New *P. vivax* drug	No	No	2026 (2025, 2029)	2024
Timor-Leste	65	Universal coverage	No	No	2019 (2017,2024)	2020
Vanuatu	77	Effective usage	Yes	No	2021 (2021, 2024)	2025
Viet Nam	67	Effective usage	No	No	2024 (2022, 2027)	2030

Figure 7. Minimum elimination scenarios in the Asia Pacific region



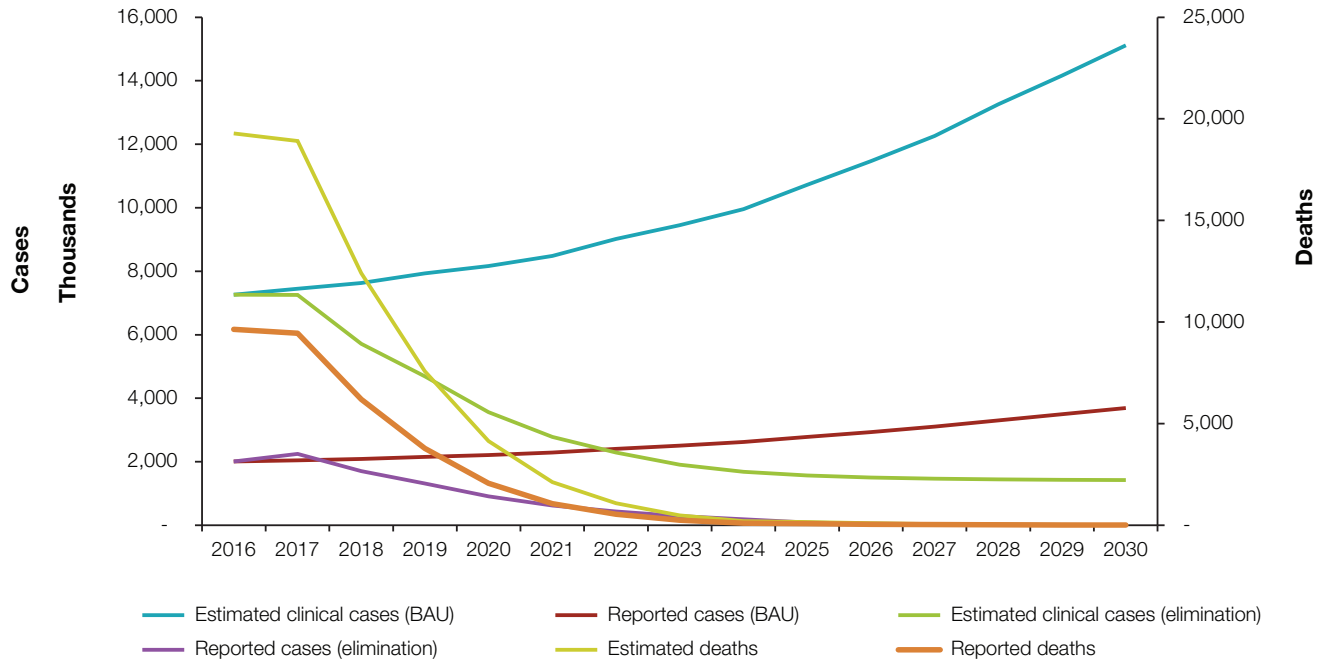
Pv – *P. vivax*; Pf – *P. falciparum*

Solomon Islands, and Vanuatu. In all other countries, elimination is possible with the scale up of existing interventions, suggesting that a "more of the same" approach is appropriate.

Figure 8 illustrates the median reported and clinical cases and deaths between 2016-30 under the "business as usual" scenario and minimum elimination scenarios for the region.

The business as usual scenario assumes that all current activities are maintained at 2015 levels, but ACT treatment failure increases to 30% by 2018. In this scenario, cases rise from an estimated 7 million in 2016 to 15 million in 2030. In the reverse scenario, cases increase to about 180 million by 2030. Elimination averts over 123 million cases and approximately 3.5 million deaths in the region over 14 years. In a "reverse" or worst case scenario, where malaria elimination interventions are halted and reduced (reverse scenario) there would be about 1 billion additional cases and 3.5 million additional deaths, costing an excess of USD 7 billion between 2016-2030.

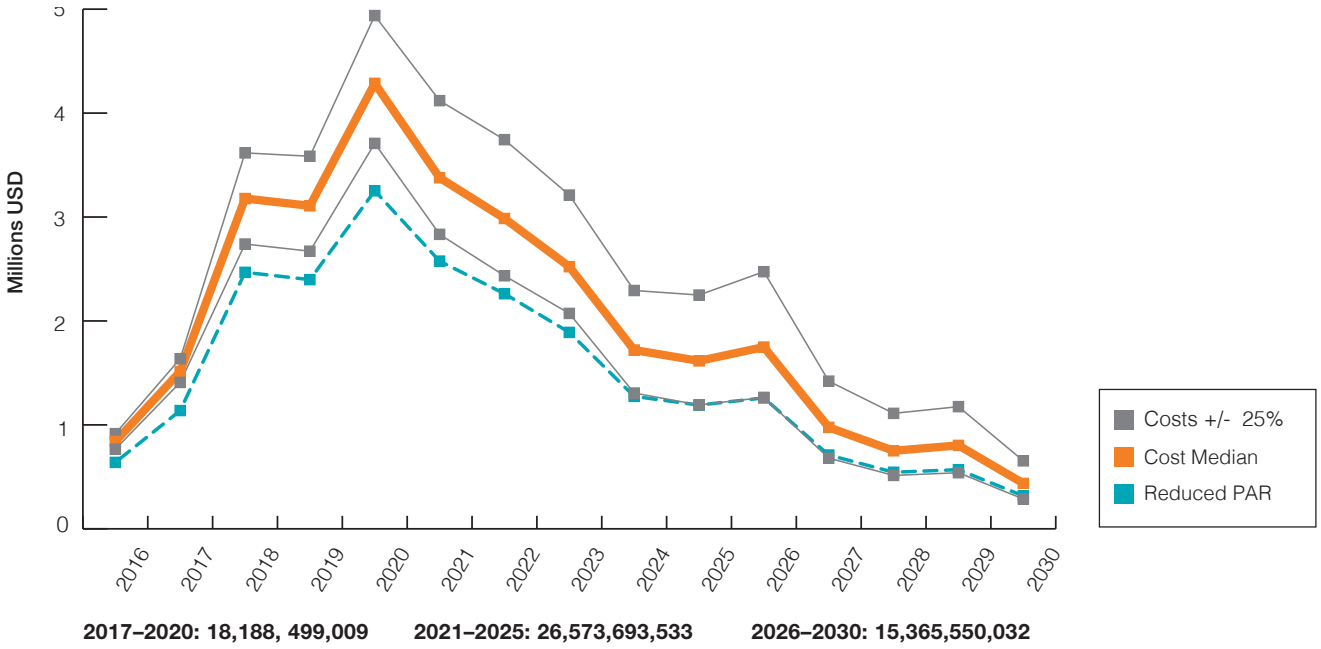
Figure 8. Transmission prediction for the Asia Pacific region, 2016-2030



BAU – Business as usual; Elim – elimination scenario

AFG – Afghanistan; BGD – Bangladesh; BTN – Bhutan; CHN – China; IDN – Indonesia; IND – India; KHM – Cambodia; KOR – Republic of Korea; LAO – Lao PDR; MYS – Malaysia; MNM – Myanmar; NPL – Nepal; PAK – Pakistan; PHL – Philippines; PNG – Papua New Guinea; PRK – Democratic People's Republic of Korea; SLB – Solomon Islands; THA – Thailand; TLS – Timor-Leste; VNM – Viet Nam; VUT – Vanuatu

Figure 9. Modeled costs of malaria elimination in the Asia Pacific region, 2016–2030



Source: Shretta et al., 2017[8]

Cost of malaria elimination through 2030

The cost of malaria elimination is shown in Figure 9 and Table 2. The total median cost to achieve malaria elimination in the Asia Pacific between 2017-2030 is estimated to be USD 29.024 billion (range: USD 23.65-36.23 million). The median cost in 2017 for the elimination scenarios is about USD 1.5 billion. Costs peak in 2020 at USD 4.29 billion, then decrease to less than USD 1 billion in 2027 and less than USD 450 million in 2030 when elimination is expected to be achieved in all 22 countries. Costs incurred are expected to continue after the elimination date as POR interventions of malaria continue.

The reverse scenario would cost an excess of USD 7 billion between 2017-2030. If interventions were only applied to 70% of the PAR in the low transmission areas (a proxy for the effect of improved targeting of interventions), the total cost would be about USD 22.49 billion.

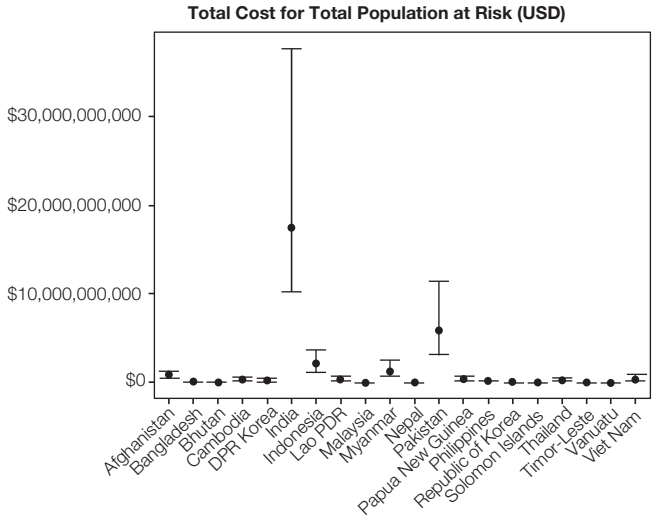
Figure 10 illustrates the country level costs for the total PAR for 2017-2030.

Figure 11 below illustrates the relative costs are skewed by sub region with over 80 percent of the costs expecting to be incurred in South Asia – most notably, India.

Economic benefits estimation

Malaria elimination will save almost USD 90 billion in economic benefits as measured by savings in health facility costs and human productivity.

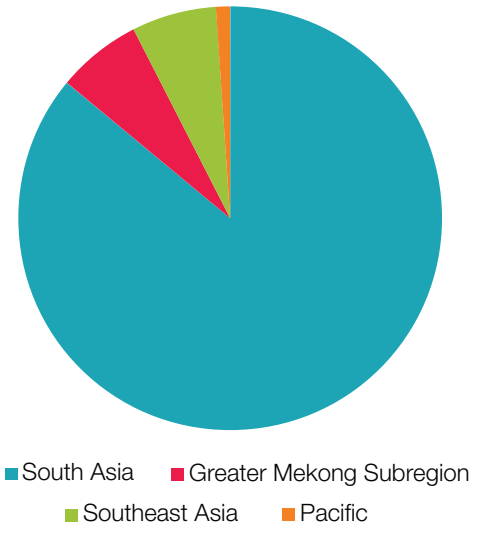
Figure 10. Modeled country level costs of the elimination scenario until 2030



Return on investment

The cost of malaria elimination should be weighed against the epidemiological and economic costs of inaction. When the net benefits of elimination compared to the cases and costs averted in the business as usual scenario of the transmission model for the period of 2017 to 2030, the median ROI for each additional dollar invested in malaria elimination was calculated to be 6:1. This increases to 7:1 if interventions are better targeted in low risk areas.

Figure 11. Relative modeled costs by subreion (2017-2030)



Financial gap

A median resource envelope of about USD 3 billion is needed annually to achieve elimination between 2018-2020. Total financing for the region is projected to be USD 0.5 billion annually for 2018-2020. Therefore, the anticipated gap is therefore likely to be 80% of the resources required for elimination.

Discussion and opportunities for resource mobilization

This analysis compared the monetized value of expected benefits from malaria elimination to the investment costs over a 14-year investment period (2017–2030), demonstrating a median return of about six times the investment. The estimates on morbidity and mortality averted from malaria elimination are conservative as they do not incorporate other potential benefits on tourism, cognitive development, and other regional externalities such as increased health security. Despite this the ROIs remain robust, comparable to those obtained for other high impact investments such as immunization programs and cardiovascular disease research (Ozawa *et al.,* 2016).

The study found that by employing a variety of existing and new interventions, all countries in Asia Pacific could eliminate malaria by 2028 – two years before the 2030 APLMA regional goal. The health, social, and economic returns are potentially formidable. Malaria elimination will save about 400,000 lives and avert over 123 million cases, translating to economic benefits of almost USD 90 billion. Successfully achieving elimination, however, will require sustained financial resources.

Table 2. Summary of meidan costs and benefits, 2017-2030

Scenarios compared	Total cost (USD)	Estimated clinical cases averted	Deaths averted	Economic benefits (USD)	Incremental cost (USD)	ROI
Business as usual vs. elimination (with resistance assumption)	29.024 billion (IQR: 23.64-36.23) 21.85 billion	123.14 million (estimated clinical) 16.54 million (reported)	386,167 (estimated) 193,084 (reported)	87.73 billion	14.05 billion	6:1
Business as usual vs. elimination (baseline)	28.953 billion (IQR: 23.38-35.72)	92.23 million (estimated clinical) 11.68 million (reported)	264,322 (estimated clinical) 132,161 (reported)	72.90 billion	13.79 billion	5:1
Reverse vs. elimination (with resistance assumption)	NA	845.73 million	3.487 million	N/A	6.693 billion	N/A

Our model estimates that the total cost of achieving elimination and POR is about USD 29.02 billion (range: USD 23.64-36.23 billion) over 14 years or USD 12 billion between 2017-2020. Total financing for malaria in the Asia Pacific in 2016 was estimated about USD 450 million. Using co-financing data from Global Fund concept notes, total financing for malaria is projected at USD 1.4 billion between 2018-2020, leaving an annual gap of about USD 2.5 billion or 80% of the estimated cost of elimination. Many countries in the region continue to rely on Global Fund resources to provide almost 50% of their total financing for malaria elimination. However, given declining trends in malaria burden and the region's rising economic status, this level of support is not likely to be sustained in subsequent years. Political and policy changes in other donor constituencies also pose similar risks. Although domestic financing for malaria has increased by 46% in Asia Pacific between 2015-2017 compared to 2012-2014, the resources required far exceed those available.

Many malaria-eliminating countries are already in the World Bank's middle-income group and the IMF projects average annual GDP growth rates of 3-10%, which means that economies in Asia will double or triple in size in the next decade. In projecting GDP growth rates to 2020, four countries in Asia that are currently LMICs (Bhutan, Indonesia, the Philippines, Sri Lanka) will surpass the World Bank threshold for lower-middle-income economies of USD 4,125 GDP per capita. This means that while there is increased potential for domestic financing, more countries will start to graduate out of aid eligibility. Of the 22 countries in the Asia Pacific region, three are currently LICs, 15 are LMICs, and three are UMICs and one is an UIC. Eighteen are currently eligible for Global Fund financing (Global Fund, 2017) – out of which an additional two countries will be receiving the final transitional grants in the next two years (the Philippines and Sri Lanka).

The potential consequences of funding reductions at this critical juncture can be serious. A systematic review of malaria resurgence found that interruption of financing was one of the most critical factors that led to 75 resurgence events in the 61 countries reviewed (Cohen, 2012). Our analysis estimates that scaling back interventions in the Asia Pacific could lead to an additional 3.5 million deaths, almost 1 billion cases, and economic costs of almost USD 7 billion. Emerging artemisinin resistance further threatens the gains made against malaria and regional health security with estimates of 9,560 excess deaths and USD 51 million in productivity losses annually (Lubell, 2016). As external funding decreases, new revenue generation, prioritization of domestic funding, and improved efficiencies in the existing malaria envelope need to be explored.

The Asia Pacific region's unprecedented economic growth has fueled the potential to scale up domestic resources for health and development. In 2015, alone, the region generated two-fifths of the global GDP (in 2011 PPP). Real GDP growth in China, India, and member states of the Association of Southeast Asian Nations (ASEAN)[h] is projected to be about 6.2% for 2016–2020 (OECD, 2016). The economies of the 10 ASEAN member states collectively form the world's seventh largest economy (ASEAN, 2015). The region is expected to continue to undergo rapid economic growth and industrialization, led by China and India – the two fastest growing economies in the world (World Bank, 2016). In addition, Bangladesh, Indonesia, Pakistan, the Philippines, ROK, and Viet Nam are six of 11 countries globally that have been identified as the "Next 11" because of their high potential to become among the world›s largest economies in the 21st century (Goldman Sachs, 2007). The region continues to be the world's top destination for foreign direct investment attracting USD 527 billion in 2015, up 9% from 2014. Investments in Asia are driven predominantly by the growth and success of the private sector, particularly export-oriented multinationals investing in manufacturing as well as economic liberalization by governments.

Along with economic growth, the continent has also seen major gains in health and social development indicators. Life expectancies have grown by more than 15 years between 1970 and 2010 (OECD, 2012). Child mortality fell by two thirds, from over 7.214 million in 1990, to 2.406 million in 2015 (Suzuki, 2015). Government spending on health as a percentage of GDP has increased in about two thirds of the region's economies since 2000; at the same time however, the region is also experiencing an epidemiological transition with aging increasingly becoming a major concern, particularly amongst populations living at relatively low per capita income levels. This may impact productivity in the near future with a risk of Asia growing old before becoming affluent.

While the region has enjoyed robust growth in recent years, this growth is unbalanced, with remarkable differences in the levels of income and the development of the social sectors across the countries. China's GDP per capita is about 80 times that of Vanuatu. Similarly, public health expenditure in 2015 ranged from 0.8% percent of GDP in Bangladesh to 4.6% in the Solomon Islands. The economic heterogeneity has led to substantial cross-border migration, mainly as people move from less developed to more developed countries in search of job opportunities. Although East Asia saw reductions in extreme poverty from 80% in 1981 to 7.2% and South Asia from 58% to 18.7% in 2012 (World Bank, 2016b), approximately 1.2 billion people in Asia and the Pacific live below the poverty line of USD 3.10 (2011 PPP) a day and about 1.5 billon people lack access to sanitation.

h The ten ASEAN member states are Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

Countries in the region will need to harness economic growth and increase government revenue if additional domestic financing for health is to be allocated. Several opportunities for increasing revenue exist.

Tax reforms to strengthen government revenue collection

In general, tax revenue (in 2016) as a percent of GDP in the Asia Pacific countries is between 10.5% in Bangladesh to 34.6% in the Solomon Islands (World Bank, 2017) – the average for developing countries is 15%. The tax gap, or the percentage of non-grant revenue collected as a proportion of GDP, indicates government ability to strengthen and expand health access. Experts have noted that a tax gap lower than 15% may inhibit a government's ability to provide basic functions. The Addis Ababa accord for the Sustainable Development Goals recommends that countries with government revenue below 20% of GDP from taxes should progressively increase tax revenues to meet this target by 2025. Allocating a portion of tax revenue to malaria could provide a sustainable source of funding to help the region to fill the financing gap (UNGA, 2015). The opportunity to convert economic growth into public revenue however, will require an expansion of the tax base and increased efficiencies in the revenue collection system, both of which will likely require capturing the informal sector.

In many of the malaria-endemic countries in Asia Pacific, OOP expenditures account for a large proportion of total health expenditure. Tax mechanisms can be adjusted to ensure communities are able to access to services as governments simultaneously launch national health insurance schemes or other mechanisms to mitigate OOP costs. Regressive taxes, levied without consideration of an individual's ability to pay (e.g. food/sales taxes), can disproportionately affect the poor and therefore limit their ability to access malaria prevention and treatment. An assessment of a government's tax scheme can help balance regressive and progressive taxes and can help policymaking bodies identify opportunities to introduce subsidies to health services or social protection programs.

Although increasing government revenue can provide the fiscal space to commit to development targets, continued advocacy is needed to ensure that governments prioritize health and malaria elimination in their allocations.

Private sector investment

In nearly three-quarters of the economies of Asia and Pacific, the service sector accounts for more than 50% of GDP and therefore has the potential to play an essential role in addressing health and development priorities in the region and globally. In Asia, the private sector incorporates private providers, both formal and informal, that deliver health services particularly in remote, hard- to-reach areas. Civil society and large commercial companies that deliver services to their workforce or engage in philanthropic activities also play a role in extending services, particularly at the community level.

The diversification of Asia Pacific countries' economies, combined with socioeconomic changes, present a unique opportunity to engage the private sector in malaria elimination. It is likely that as the contribution of the private sector to the economy increases, they will also become increasingly involved in social development efforts across Asia (Mukala, 2016). Innovative approaches leveraging the expertise and resources of the private sector, in partnership with the public sector, are some approaches available to address the challenges of a shifting malaria financing landscape and the threat of drug resistance. Innovative private sector investment models are needed to better align incentive structures with those of traditional corporate social responsibility models. Examples of government incentives include tax relief or tax credit schemes, policies that promote expansion or diversification of programs, awards in recognition of companies that contribute to malaria elimination efforts. For example, the Cambodian Ministry of Health has developed a policy framework for public-private partnerships in the health sector. Private foundations and public-private partnerships can also play important roles in mobilizing resources. In PNG, a successful private sector partnership for health exists between Oilsearch Health Foundation and the Government of Papua New Guinea to increase health access. Similarly, tax incentives have been deployed India to stimulate pharmaceutical research and development.[i]

Private Asian companies such as AirAsia, Samsung, the Tata group, and Alibaba have become internationally recognizable brands. Air travel has doubled between 2010 and 2015, increasing connectivity and facilitating trade and tourism, which has almost quadrupled since 2000. An airline levy such as the UNITAID model could raise more than USD 300 million per year.

Networks such as the Mekong Business Initiative (MBI),[j] which is focused on promoting business environment reforms and private sector development in the GMS, can play a critical role together with other regional platforms that link the public and private sectors. MBI focuses on enterprise development, commercial law, financial services, incubation, and acceleration (ADB, 2017). Activities could include: supporting the creation of new and innovative approaches; commodity development utilizing private sector's distribution networks and transportation (e.g., helicopters, trucks, boats, etc.) to deliver commodities to hard-to-reach communities; technology transfer; and supply chain management, among others.

i http://ris.org.in/images/RIS_images/pdf/dp176_pap.pdf
j The MBI aligns to the ADB Strategy 2020 focus on private sector development, as well as the GMS Economic Cooperation Program Strategic Framework (2012- 2022).

The region has a number of business platforms that can be included to promote the involvement of the burgeoning private sector. For example, the ASEAN Business Club (ABC) is a leading platform that brings together leading business people from Southeast Asia to promote business integration in the context of the ASEAN Economic Community. Health can be proposed as an issue for the ABC to address as part of their business activities. The ASEAN Tourism Association covers the travel and tourism sector across the 10 Southeast Asian countries including all five GMS countries; it could support engagement of the tourism sector in malaria elimination efforts, particularly as tourism plays a major role in the economies of all GMS countries, contributing to about 30% of Cambodia's GDP and 19.3% of Thailand's economy (UCSF/MEI, 2017; UNESCAP, 2017). For example, in Indonesia, the government's efforts to open up new locations as emerging tourism destinations offers an opportunity to raise the profile of malaria, as half of the newly designated sites are in malaria endemic areas.

Multilateral funding

MDBs and partners can provide new financing opportunities to governments and the private sector, including cross-sectoral financing for health programs, incentivizing companies to invest in health interventions. They can also provide technical assistance to support governments to improve regulatory frameworks in a number of areas including health, private sector development, insurance, etc. For example, the ADB provides grants, concessional loans, and technical assistance to countries in the region. Although ADB does not finance malaria interventions specifically, it does co-fund, for example, the Rural Primary Health Services Delivery Project in PNG that aims to improve access to and quality of rural health services, which can be leveraged for malaria (ADB, 2016b). Countries can seek out additional grants and soft-loans from ADB to help frontload the costs of elimination. Since 2016, ADB has also begun piloting a regional health security grants initiative to promote health security related regional public goods including support for regional cooperation and strengthened health systems. Contributions from countries and other sources are currently being sought (ADB, 2016). In addition, ADB funds the GMS Health Security Project, which is comprised of four loans, to Cambodia, Lao PDR, Myanmar, and Viet Nam, and a grant to Lao PDR to enhance responses to emerging infectious diseases and management of other major public health threats. The project's total cost is USD 132.2 million, with the four countries contributing a total of USD 7.2 million.

Integration of malaria elimination into development and infrastructure projects

Significant infrastructure and development projects are being financed in the region, presenting and opportunity to ensure malaria prevention and treatment are extended, particularly in hard to reach areas or among isolated populations including migrant workers. In Bangladesh, the ADB country operations business plan (2016-2018), valued at USD 2.78 billion aims to support emerging development priorities of the government. The Government of Bangladesh could explore how the objectives of this loan, including infrastructure development could reinforce and support the national elimination goal. This is particularly relevant since large infrastructure projects are often underway in high transmission areas that are the hardest to reach. Multilateral and Regional Development Banks such as the World Bank and ADB can be encouraged to incorporate health impact assessments which include malaria indicators as a pre-requisite for infrastructure loans.

Regional Platforms

Regional multilateral platforms and associations will be crucial in any effort against malaria. The ASEAN, comprising 10 countries of the Southeast Asia Region, also has a wider network in the form of the 18-member East Asia Summit. Involving ASEAN, its associated entities, and other platforms will help create and maintain regional momentum and commitment from political leadership. International and regional funds pooling resources from other sources including governments, aid agencies, development institutions, corporations, foundations, and individuals may efficiently finance certain causes or objectives. The pooling of resources reflects a shared commitment to fight specific problems at the local, regional, or global levels. This is particularly relevant for Asia Pacific where cross-border collaboration will be integral for the region to eliminate by 2030 given the growing trend in insecticide and drug resistance. As an example, the Regional Artemisinin Initiative 2 Elimination (RAI2E) grant, a regional funding mechanism for the GMS, may be expanded to include pooling from other sources of financing. A recent report investigating the potential for a regional health security fund discusses other options further (UCSF/MEI, 2017).

Innovative financing

Use of innovative financing mechanisms such as (a) instruments for resource generation and pooling and (b) fund deployment mechanisms; both of these are favorably viewed as a means to meeting the short- and medium-term needs of health and other development sectors. These may include health bonds, debt swaps, and blended financing mechanisms. Debt conversion mechanisms shift resources away from debt repayments towards development spending. An example is a "debt buy-down" where portions or an entire debt of a country is paid by a donor in exchange for achieving predetermined results. In a debt swap, a lender or donor writes off parts of a country's debt; in turn, the government invests an agreed amount on a specific program. Debt swaps have been used in several countries by the Global Fund, Australia, and Germany. Partnerships between MDBs and traditional

donors can provide short-terms solutions and shared risk, tying key performance indicators linked to disbursements. Several MDBs are currently engaged in these models including ADB, the Inter-American Development Bank, the Islamic Development Bank, and others in collaboration with the Bill & Melinda Gates Foundation, the Global Fund and other partners (USCF/MEI, 2017). Social impact bonds and development impact bonds are other types of performance-based contracts that have been implemented in selected settings. One example is the Mozambique Malaria Performance Bond, which is being used to raise funding from "outcome funders," or investors interested in both financial and social returns (Murray, 2016; Devex Impact, 2016). As the first "malaria bond" of its kind, investors are only paid when the malaria program meets its targets (Devex Impact, 2016). These innovative instruments have been used to raise financing for health and other sectors, such as education and environment (Kumar, 2013).

"Sin taxes," or taxes on harmful products such as alcohol and tobacco, are another way to potentially increase supplementary revenue for health. Many of these revenue-generating structures already exist within countries in Asia such as Indonesia, Viet Nam and the Philippines. The Philippines which instituted a "sin tax" that generated an additional USD 2.3 billion in revenue during the first two years of implementation (Paul J., 2015). As a result, health funding in the Philippines increased by 57.3% in 2014 and 63.2% in 2015 in comparison to 2013. Other types of taxes include levies on sugar-sweetened beverages, foreign currency transactions, and transactions in international finance markets. The large revenue base and the long-term nature of taxes make such instruments reliable and sustainable sources of funding. Similarly, governments could also consider leveraging national lotteries and earmarking financing for elimination In Costa Rica, earmarked funds are dedicated to purchasing vaccines, while in South Africa lotteries generated US$142 million for social causes (APLMA, 2015c).

Social health insurance

Social health insurance and other revenue-generating measures offer the potential to support malaria elimination. However, current health insurance schemes do not adequately provide for preventive services that are "a public good". A critical appraisal of national health insurance schemes in Asia Pacific could assess the extent to which universal health coverage indicators include basic primary health care functions necessary for malaria elimination, such as surveillance and mechanisms to expand their mandate be sought. For example, Bangladesh has created a National Health Care Financing Strategy (2012–2032) that outlines its plan to introduce insurance into the country. The scheme includes government revenue subsidies for people below the poverty line and contributions from the formal sector. The health insurance scheme could reduce OOP spending and close the gap for core malaria interventions that will be required to eliminate the disease.

Efficiencies

In addition to increasing available health revenue and allocating additional resources, improved efficiencies can generate cost-savings, freeing up resources to cover financing gaps. Assessing and identifying current inefficacies and drivers of inefficiency can increase utilization of current funds. For example, the malaria programs can work with other ministries such as agriculture, or with other mosquito borne disease programs such as dengue, to integrate approaches and interventions. Increasing program efficiencies can help maximize limited resources. Greater efficiency can be achieved by targeting and implementing an optimal mix of malaria interventions that will create the most impact; or by maximizing the impact of current inputs to the malaria program. While there is currently no global recommendation for an optimal mix of interventions to achieve malaria elimination, technical or programmatic efficiencies may significantly decrease the projected cost of elimination. Reviewing efficiency of the malaria program on an annual basis, including an efficiency assessment as a pre-requisite for donor funding and linking disbursements to efficiency indictors will mitigate future inefficiencies.

Malaria elimination and health security

Health security and universal health care (UHC) have risen to prominence in Asia Pacific's health and development agenda. The diversity of demographic trends in the region creates opportunities for capital flows as well as cross-border risk sharing. As countries in the region become more interconnected through increased infrastructure and air links, health security is also becoming a major concern. Recent outbreaks of severe acute respiratory syndrome, H5N1 ("avian flu") and H1N1 ("swine flu") influenza, Middle Eastern respiratory syndrome coronavirus, Ebola, and more recently the Zika virus have highlighted the need for governments to invest in health security to tackle emerging and re-emerging infectious diseases. Artemisinin resistance similarly poses a risk to health security. Investing in malaria elimination has a direct positive contribution to the health security of the countries and communities involved. Malaria's key interventions—including strengthened surveillance, health information systems, disease surveillance, and preparedness—provides a platform to tackle other emerging infectious diseases by improving the capacity to detect and report disease outbreaks, respond faster to public health emergencies, and collaborate across borders (APLMA, 2015b, 2016). Malaria elimination can be viewed as an entry point to strengthen health systems and has the potential to highlight how elimination can lead to increased equity. In low transmission settings, where cases cluster among high risk populations, programs must tackle areas and communities that do not have access to critical health services. These systems will also be able to

better deliver universal health coverage, and the funds no longer needed for malaria can be redirected to tackle other pressing health challenges. Given the context of declining malaria case numbers across the region, malaria advocacy will need to be tied to a wider narrative that includes other communicable diseases such as dengue, which has seen a dramatic resurgence in recent years, and Zika as part of a regional health security response.

Advocacy and leveraging political assets

An important consideration is the expanded role of advocacy to increase political support and resources for elimination. Many of the Asia Pacific malaria-endemic countries have political assets that can be leveraged to increase political influence. Deploying support to mobilize these political assets towards a country resource mobilization objective will ensure strategies are aligned with the malaria program and will increase the sustainability of future advocacy and accountability efforts. Leaders, political figures and celebrities can serve as ambassadors for malaria. Drawing on country-level political assets can also ensure continuity in political engagement. For example, in Bangladesh, the Malaria Elimination Oversight Committee, backed by the Prime Minister, can bridge the national program with high-level leadership and promote malaria on the national health and development agenda.

Crowd funding or crowdsourcing

Crowd funding has been used to fund a wide range of innovative projects such as health and social entrepreneurship projects. Platforms such as Facebook, Twitter, the Global Citizens movement and Change.org have helped raise awareness and traction on a number of social issues. In 2015, it was estimated that over USD 34 billion was raised this way globally (Barnett, 2015). Examples are Product (RED) created by Bono and Bobby Shriver in 2006 to fund HIV/AIDS programs in Africa. (RED) works with the world's most iconic brands and organizations to develop (RED)-branded products and services, that when purchased, trigger corporate giving to the Global Fund. To date, (RED) has contributed over USD 365 million to support Global Fund HIV/AIDS grants in Ghana, Kenya, Lesotho, Rwanda, South Africa, Swaziland, Tanzania and Zambiak. Similarly, the "Ice Bucket Challenge" for amyotrophic lateral sclerosis helped raised USD 115 million (NYT, 2016). Such a mechanism could be used to earmarked funds to the Global Fund or a regional financing mechanism at the same creating awareness for malaria.

Emerging donors in the region

Economic growth also brings opportunities for countries like China and Japan, to contribute to regional public goods, like malaria elimination. As of 2011, China contributed 33% of its foreign aid to Asia and 4% to Oceania. China's interest in the Pacific Islands is growing, and as of 2015, China was on track to overtake Japan to become third largest donor to this sub-region. PNG has already benefited from China's engagement on malaria elimination efforts in a trilateral agreement between PNG-Australia-China to increase lab capacity. Opportunities for China to engage other Asia Pacific countries on malaria could also emerge from the One Belt, One Road (OBOR) initiative leveraging the issue of interconnectivity of malaria transmission across borders. Similarly, Japan's priority investments and commitment to UHC and biotech research align with the region's malaria elimination goals. Roughly 43% of the Global Health Innovation Technology Fund (GHIT), a public-private partnership with the Bill & Melinda Gates Foundation, has been allocated to malaria-related research and product development.

Ensure smooth transitions from donor financing

Many countries will graduate in income status and will graduate from donor financing. Malaria programs, given the low disease burden, may lose eligibility before then. In addition to pursuing additional domestic financing and meeting current co-financing requirements of existing grants, countries should appropriately plan the transition from donor to domestic funding sources three to five-years in advance of the actual transition.

Limitations of this study

As outlined in the Methods section, the transmission model was not designed to explore scenarios below national level. This was due to limitations in computing power and available data which would be needed to parameterise a subnational level model. Future work will adapt the METCAP model to be applied at subnational level for individual countries.

Beyond the benefits of achieving malaria elimination as explained in this report, other benefits are likely, but are harder to quantify. As a byproduct of national elimination, other positive externalities such as increased tourism, a strengthened health system, and improved regional health security could result. In addition, elimination may bring significant benefits to other regional public goods including opportunities to create stronger cross-border disease coordination. This investment case provides robust evidence for the minimum benefits of continued prioritization of funding for malaria, as well as options for resource mobilization, and can be used to develop an advocacy strategy for increased domestic and external funding for improving health security and reaching the regional goal to be malaria-free by 2030.

A number of unknown factors and limitations impact the findings of this report. The costs of medicines and other interventions have been estimated based on available data and proxies were used when data were unavailable.

k https://www.theglobalfund.org/en/private-ngo-partners/red/

In particular, separating out the cost of interventions in integrated systems is challenging and the analysts have relied on country-level partners to apportion the amounts spent on each intervention to arrive at disaggregated costs. In addition, the costs are highly dependent on the output of the transmission model, which was developed using national-level data on incidence and intervention coverage. These estimates are subject to error, particularly in countries with heterogeneous transmission patterns. Furthermore, elimination often requires targeted interventions to risk areas or populations, rather than ubiquitous coverage to an entire country. Without subnational estimates of incidence and coverage, targeted interventions are difficult to estimate and cost.

While we have tried to estimate the effect that drug and insecticide resistance would have on cost, it is impossible at this stage to predict accurately the future extent and effect of drug and insecticide resistance and the actual interventions that would be implemented to address these. In addition, the impact and cost of known tools in the innovation pipeline have been modeled, however, the impact of new tools and approaches not yet developed is unknown and will be likely to decrease costs. Moreover, the cost of new tools is greatest at the time of adoption with economies of scale and competition driving costs down over time. It is difficult to predict how the costs of interventions may change at the regional or national levels over time.

Lastly, current assessments of reported malaria incidence have limitations. Research suggests that there may be significant under-reporting in the scale of global malaria incidence and mortality due to the weakness of health reporting and information management systems as well as widespread and undocumented use of the private sector in many endemic countries. For example, the Institute for Health Metrics and Evaluation estimated a figure of 1.2 million malaria deaths in 2010—almost double the WHO's figure of 655,000 (Murray, 2012). Similarly, a widely quoted study in *The Lancet* estimated that in India, 205,000 deaths per year could be attributed directly to malaria, which differed by more than ten times the numbers reported by the malaria program in the same year (Dhingra, 2010).

There have been various attempts at quantifying the true burden of malaria and more recent publications of the World Malaria Reports contain data on reported cases to health facilities as well as estimated cases based on a number of assumptions. This report utilizes reported cases from the World Malaria Reports as well as estimated clinical cases for the countries in the Asia Pacific region derived by Mahidol-Oxford Tropical Medicine Research Unit (Maude et al. forthcoming). These estimates were obtained by combining and triangulating data from a variety of data sources. The revised burden data were used to populate the models used in this analysis. Both reported and estimated clinical cases are depicted in the graphs. Nevertheless, the wide variation in estimates of burden makes it harder to be sure of the resources required to eliminate the disease. Without an informed and complete understanding of the current cartography of malaria risk and prevalence, future projections of the cost of eliminating malaria face overwhelming uncertainty. We believe that the estimated benefits of elimination are conservative, as we did not account for the impact of elimination on tourism or on cognitive development, as there are no reliable quantitative estimates on how malaria may impact these. We also did not account for the impact of population movement, which would increase the costs of elimination via importation. Because of these uncertainties, estimated costs can only provide an indicative guide or baseline to help determine financing needs. It is therefore important that economic estimates are constantly reviewed in the light of new information, through to 2030. Importantly, due to the diversity of the region, further analysis is required to adapt the model to individual country settings and develop country-level estimates based on the national context. This, however, makes it even more important that funds can be put in place quickly to match currently expected costs.

Conclusion

Global progress against malaria has been dramatic over the past decade. These gains, however, have been driven by substantial political and financial commitments that must be sustained to avoid a resurgence of malaria. There are several critical reasons why malaria elimination should receive a special focus for financing. Malaria is a major and ongoing cost driver, burdening national health systems and eliminating the disease will confer public health benefits as well as major cost savings to national health systems. Although the short-term investment needed may seem substantial, these are time-limited as costs taper off significantly as more countries eliminate the disease. Secondly, there is a strong correlation between the decline in malaria burden and sustained financing. Declining financing for malaria is an imminent threat to malaria elimination, the spread of drug resistance, and regional health security in the Asia Pacific region. This investment case provides compelling evidence for the benefits of continued prioritization of funding for malaria, and can be used to develop an advocacy strategy for increased domestic and external funding for the region to reach its goal to be free of malaria by 2030.

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Annex 1. Financing for malaria in the Asia Pacific region

Table A-1. Projected financing for malaria in Asia Pacific countries 2018-2020 (USD) by source

	2017	2018	2019	2020	TOTAL
Afghanistan					
Total need (NSP)	26,783,269	26,783,269	26,783,269	26,783,269	107,133,076
Domestic resources	887,732	887,732	887,732	887,732	3,550,928
Donor financing	2,883,026	9,141,288	9,141,288	9,141,288	30,306,891
Bangladesh					
Total need (NSP)	20,857,513	26,234,743	27,209,551	27,209,551	127,072,661
Domestic resources	5,760,790	19,497,481	19,497,481	19,497,481	68,858,920
Donor financing	13,203,477	10,220,000	10,220,000	10,220,000	50,473,323
Bhutan					
Total need (NSP)	2,154,701	1,530,595	1,681,382	1,933,830	9,299,898
Domestic resources	1,141,191	358,851	358,851	358,851	3,308,085
Donor financing	936,284	680,962	680,962	680,962	3,635,658
Cambodia					
Total need (NSP)	50,354,592	50,354,592	50,354,592	50,354,592	251,772,962
Domestic resources	6,551,093	6,926,275	6,926,275	6,926,275	33,231,803
Donor financing	15,294,124	20,444,984	20,444,984	20,444,984	84,137,519
China					
Total need (NSP)	17,620,404	17,620,404	17,620,404	17,620,404	88,102,020
Domestic resources	17,620,404	17,620,404	17,620,404	17,620,404	88,102,020
Donor financing	0	0-	0	0	0
DPRK					
Total need (NSP)	5,478,218	5,478,218	5,478,218	5,478,218	27,419,244
Domestic resources	2,277,400	2,277,400	2,277,400	2,277,400	11,301,400
Donor financing	1,979,161	2,694,627	2,694,627	2,694,627	13,842,125
India					
Total need (NSP)	326,268,575	326,268,575	326,268,575	326,268,575	1,682,353,892
Domestic resources	98,397,636	$66,666,667	66,666,667	66,666,667	387,850,032
Donor financing	57,229,978	$21,668,817	21,668,817	21,668,817	126,313,458
Indonesia					
Total need (NSP)	30,820,108	62,328,470	38,633,244	31,606,567	211,039,469
Domestic resources	20,637,745	33,066,134	33,066,134	33,066,134	138,711,425
Donor financing	32,990,920	21,772,035	21,772,035	21,772,035	113,018,959

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Table A-1: continued

	2017	2018	2019	2020	TOTAL
Lao PDR					
Total need (NSP)	11,516,425	9,689,776	17,146,779	10,282,183	72,788,480
Domestic resources	2,034,023	1,968,966	1,968,966	1,968,966	9,954,785
Donor financing	3,411,170	5,573,814	5,573,814	5,573,814	24,797,796
Malaysia					
Total need (NSP)	2,813,299	2,813,299	2,813,299	2,813,299	14,066,496
Domestic resources	2,813,299	2,813,299	2,813,299	2,813,299	14,066,496
Donor financing	0	0	0	0	0
Myanmar					
Total need (NSP)	122,599,361	84,114,502	92,181,303	68,473,309	461,751,566
Domestic resources	7,724,916	27,473,329	27,473,329	27,473,329	96,582,334
Donor financing	29,947,493	33,123,156	32,853,156	33,123,156	185,099,235
Nepal					
Total need (NSP)	5,591,782	5,591,782	5,591,782	5,591,782	27,677,964
Domestic resources	757,793	4,231,124	4,231,124	4,231,124	14,140,068
Donor financing	2,840,263	1,449,349	1,449,349	1,449,349	10,211,065
Pakistan					
Total need (NSP)	43,643,679	33,314,122	43,488,565	33,087,440	229,461,993
Domestic resources	12,178,383	27,246,960	27,246,960	27,246,960	105,517,723
Donor financing	15,019,189	13,077,626	13,077,626	13,077,626	65,127,784
Philippines					
Total need (NSP)	13,360,148	5,372,960	6,361,790	6,806,251	43,571,086
Domestic resources	7,481,148	9,768,995	9,768,995	9,768,995	44,195,209
Donor financing	5,702,884	3,554,272	3,554,272	3,554,272	19,754,929
PNG					
Total need (NSP)	59,411,140	61,274,447	61,274,447	61,274,447	302,508,997
Domestic resources	11,312,401	11,312,401	11,312,401	11,312,401	56,278,418
Donor financing	11,313,771	8,267,274	8,267,274	8,267,274	44,091,057
ROK					
Total need (NSP)	538,495	538,495	538,495	538,495	2,692,475
Domestic resources	538,495	538,495	538,495	538,495	2,692,475
Donor financing	0	-0	0	0	0
Solomon Islands					
Total need (NSP)	10,357,818	10,357,818	10,357,818	10,357,818	54,094,746
Domestic resources	2,424,000	610,449	610,449	610,449	5,528,347
Donor financing	2,923,018	3,399,630	3,399,630	3,399,630	17,582,769
Sri Lanka					
Total need (NSP)	9,436,198	9,436,198	9,436,198	9,436,198	46,544,831
Domestic resources	6,551,093	1,247,212	1,247,212	1,247,212	16,194,615
Donor financing	1,624,847	833,333	833,333	833,333	4,931,272

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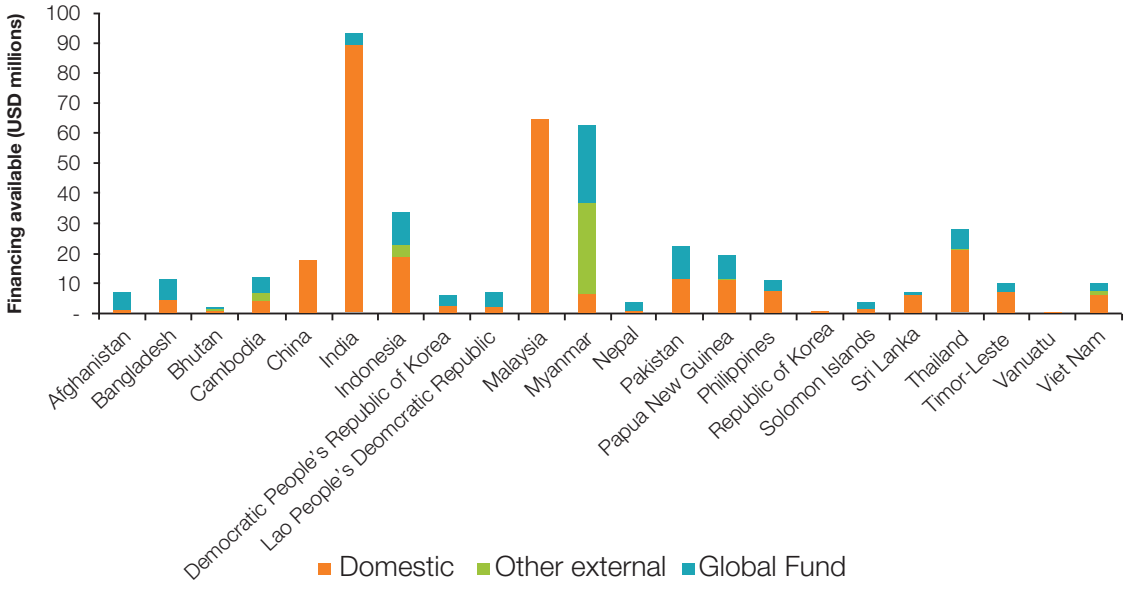
Table A-1: continued

	2017	2018	2019	2020	TOTAL
Thailand					
Total need (NSP)	47,793,973	47,793,973	47,793,973	47,793,973	238,969,865
Domestic resources	21,111,550	5,002,088	5,002,088	5,002,088	57,229,364
Donor financing	10,188,159	8,401,415	8,401,415	8,401,415	42,489,115
Timor-Leste					
Total need (NSP)	9,776,531	9,776,531	9,776,531	9,776,531	50,864,441
Domestic resources	5,703,111	2,103,576	2,103,576	2,103,576	18,967,354
Donor financing	1,571,838	3,689,708	3,689,708	3,689,708	15,768,638
Vanuatu					
Total need (NSP)	4,359,131	3,866,938	4,751,367	4,052,621	20,935,889
Domestic resources	166,359	166,359	166,359	166,359	831,795
Donor financing	1,287,297	1,124,041	1,124,041	1,124,041	5,946,717
Viet Nam					
Total need (NSP)	18,296,980	16,084,751	15,946,486	15,531,693	81,068,986
Domestic resources	6,565,425	10,391,910	10,391,910	10,391,910	44,306,580
Donor financing	8,634,802	11,691,157	11,691,157	11,691,157	47,673,761
Asia Pacific					
Total need (NSP)	**839,832,340**	**816,624,458**	**821,488,068**	**773,071,046**	**4,151,191,037**
Domestic resources	**240,635,987**	**252,176,107**	**252,176,107**	**252,176,107**	**1,221,400,176**
Donor financing	**218,981,701**	**180,807,488**	**180,537,488**	**180,807,488**	**905,202,071**
Gap	**380,214,652**	**383,640,863**	**388,774,473**	**340,087,451**	**2,024,588,790**

Figure A-1. Projected financing for malaria in Asia Pacific countries (USD millions), 2017



Annex 2. GDP and government expenditures on health

Country	GDP per capita (USD) (2015)	Total health expenditure (2014)	Government health expenditure as a % of total health expenditure (2014)	Government health expenditure as a % of GDP (2014)	% of government expenditure on health (2014)
Afghanistan	594.30	8.2	35.8	2.9	12
Bangladesh	1,211.70	2.8	27.9	0.8	5.7
Bhutan	2,665.99	3.6	73.2	2.6	8.0
Cambodia	1,158.70	5.7	22	1.3	6.1
China (Yunnan province)	8,027.68	5.5	55.8	3.1	10.4
DPRK	No Data				
India	1,598.26	4.72.8	30.0	1.4	5.0
Indonesia	3,346.50	1.9	37.8	1.1	5.7
Lao PDR	1,818.44	4.2	50.5	0.9	3.4
Malaysia	9,768.33	2.3	55.2	2.3	6.4
Myanmar	1,161.48	5.8	45.9	1.0	3.6
Nepal	743.32	2.6	40.3	1.4	11.2
Pakistan	1,434.69	4.3	35.2	0.9	4.7
Philippines	2,904.20	7.4	34.3	1.6	10
PNG	2,268.17	4.7	81.3	3.5	9.5
ROK	27,221.50	7.4	54.1	4.0	12.3
Solomon Islands	1,934.86	5.1	91.9	4.6	12.5
Sri Lanka	3,926.20	3.5	56.1	2.0	11.2
Thailand	5,814.77	4.1	77.8	3.2	13.3
Timor-Leste	1,157.99	1.5	90.4	1.3	2.4
Vanuatu	2,805.32	5.0	89.8	4.5	17.9
Viet Nam	2,111.14	7.1	54.1	4.8	14.2

Source: World Bank (2017)

Annex 3. Income classification of Asia-Pacific countries (2016)

Lower-income countries	Lower-middle income countries	Upper-middle income countries	Upper-income countries
Afghanistan	Bangladesh	China	ROK
DPRK	Bhutan	Malaysia	
Nepal	Cambodia	Thailand	
	India		
	Indo		
	Lao		
	Myanmar		
	Pak		
	PNG		
	Philippines		
	Solomon Islands		
	Sri Lanka		
	Timor Leste		
	Vanuatu		
	Vietnam		

Annex 4. Methods and Data Sources

To estimate the costs of malaria elimination, we used outputs from dynamic epidemiological transmission models that simulated the impact of various scenarios on the malaria burden across 22 Asia Pacific countries from 2016 to 2030. A full description of the mathematical model and the parameters driving the model is available elsewhere (Silal et al., forthcoming). The model uses four infection classes (i.e., severe, clinical, asymptomatic and detectable by microscopy, and asymptomatic and undetectable by microscopy) in estimating the impact of malaria interventions on *P. falciparum* and *P. vivax* transmission. *P. vivax* infections were characterized by relapses of malaria arising from persistent liver stages of the parasite (i.e., hypnozoites). The relationship between glucose 6-phosphate dehydrogenase deficiency (G6PDd) and *P. vivax* malaria was captured using existing estimated G6PDd proportions in the population (unpublished data from the Malaria Atlas Project). The model was designed to be spatially explicit with interconnected patches representing individual countries. A diagram of the model structure is shown in Figure A4-1A and A4-1B.

Data used to calibrate and validate the model were sourced from World Malaria Reports (2008-2016), disease burden estimates from Mahidol-Oxford Tropical Medicine Research Unit (MORU) (Maude et al. forthcoming), and peer-reviewed literature. Mahidol-Oxford Tropical Medicine Research Unit in collaboration with a number of partners has derived revised burden estimates for the countries in the Asia Pacific region by combining and triangulating data from a variety of data sources (data from the WMR, a systematic review on access to healthcare, completeness of reporting and the sensitivity of diagnostic tests). In 2015, 2,436,813 total confirmed cases of malaria in the 22 countries were reported in the WMR whereas MORU estimates that the actual number of malaria cases in these 22 countries in 2015 was 4,809,884 (3,141,137-31,153,623). These revised burden data were used to populate the models used in this analysis. The model was validated separately against the estimated burden of disease for *P. falciparum* and *P. vivax* and accumulated case mortality. While reported coverage of interventions (particularly LLINs and IRS) were included in the model to inform changes in incidence, there was little available data on health system advances between 2000 and 2015

Figure A4-1A. Malaria transmission model structure for *P. falciparum*

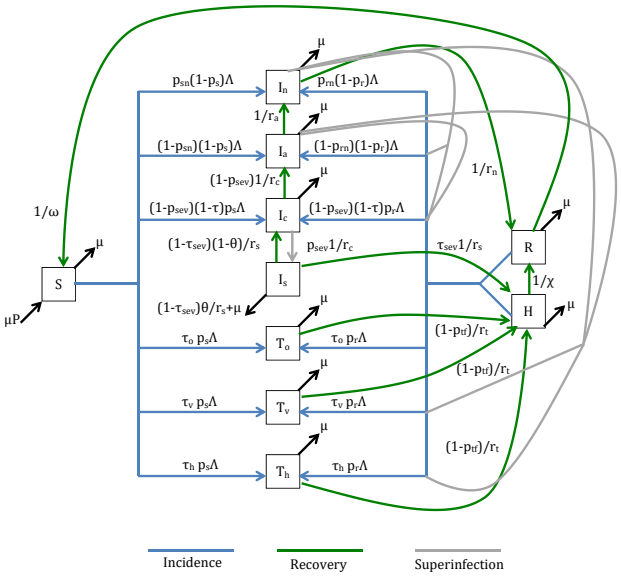


Figure A4-1B. Malaria transmission model structure for *P. vivax*

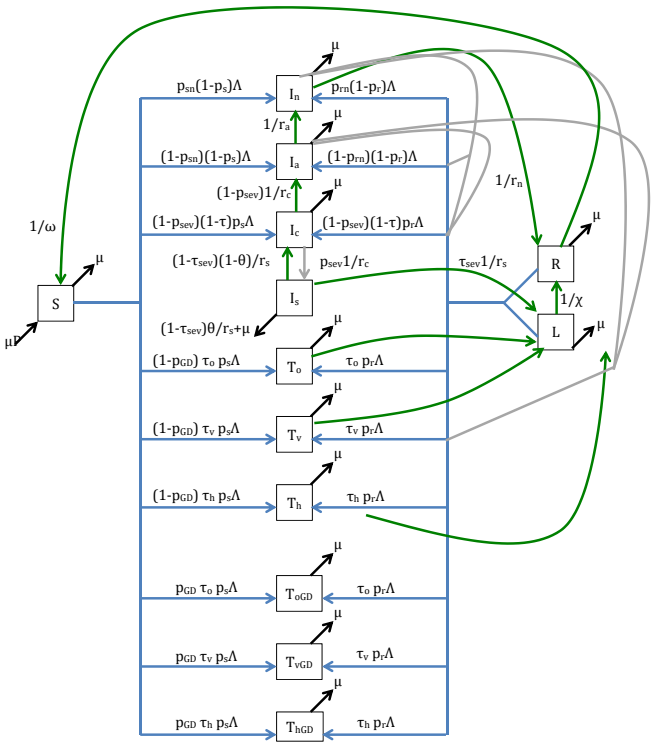


Table A4-2. Modeled scenarios

	Scenario	Description
1	Business as usual	Continue all interventions at 2014 levels from 2016 through 2030
2	Reverse scenario 1	• Business as usual • IRS activities ceased
3	Reverse scenario 2	• Reverse scenario 1 • Distribution of new LLINs ceased
4	Reverse scenario 3	• Reverse scenario 2 • Treatment rates reduced by 50%
5	Universal coverage	• Business as usual • Coverage test and treat increased from 2017 onwards in a linear fashion over eight years to 80% by 2025 • Quinine is switched to injectable artesunate for management of severe disease in 2017
6	IRS	• Universal coverage • IRS coverage in 2017 doubled in a linear fashion over eight years
7	Effective usage	• Universal coverage • Effectiveness of LLINs increased • Surveillance increased
8	New *P. vivax* treatment	• Effective usage • Replace primaquine with a new *P. vivax* treatment
9	New LLINs	• New *P. vivax* treatment • Life of LLINs doubled
10	New *P. falciparum* treatment	• New LLINs • First-line ACT replaced with new candidate for *P. falciparum* treatment
	Assumption	**Description**
A	Artemisinin resistance	5% probability of treatment failure from ACTs across all countries is constant until 2018 and then increased to 30% through 2025
B	MDA	Five annual rounds of MDA at 50% coverage from 2018 starting four months before the peak of the transmission season
C	LLINs	Scaling up LLINs to 80% effective coverage deployed in a 3-year cycle (50%, 25% and 25%)

(such as the introduction of community health workers); thus, these were imputed based on observed changes in reported incidence. The mortality predicted by the model was validated against reported deaths.

We modeled four counterfactual scenarios (No. 1-4 in Table A4-2), including one business as usual scenario and three reverse scenarios that simulated the potential impact of scaling down the malaria program. The six elimination scenarios (No. 5-10 in Table A4-2) were modeled sequentially to increase in complexity and in the number of interventions included. Across all 10 scenarios, we applied three assumptions around the likelihood of artemisinin resistance, the use of MDA, and the scale up of LLINs to 80%. For each country, we determined the minimum scenario that would achieve malaria elimination, defined here as one year with less than one reported clinical case. Since the model does not distinguish between indigenous and imported cases, we assumed that a certain threshold of cases are imported, which we subtracted from the model outputs. The elimination threshold for each country was determined using a regression model of imported clinical cases from reported data based on countries that have recently eliminated malaria.

These additional scenarios produced a total of 80 scenarios (with and without resistance; with and without MDA; and with and without LLIN scale up to 80%).
In addition, we simulated the effect of improved targeting of malaria interventions on both costs and epidemiological outputs. We did this by reducing intervention coverage by 30% among the PAR for all scenarios, with and without the resistance and MDA assumptions.

Cost projections

We built a cost estimation model aligned with the outputs of the transmission model to estimate the costs associated with implementing each of the scenarios above. We included the costs of OP and IP treatment, LLIN distribution, IRS (where applicable), supply chains, surveillance,

community health workers, information, education, and communication, training, MDA, new treatments such as a radical cure for *P. vivax* (i.e., tafenoquine), and new LLINs in the cost model. Unit costs were obtained from country reports, expert opinion, published literature, WHO CHOICE data and other proxies when data were not available. Costs were discounted by 3%.

Benefits estimation

We used outputs from the transmission model to estimate the benefits of malaria elimination. We calculated the deaths and cases averted from malaria elimination by obtaining the difference between the outputs of the elimination and business as usual and reverse scenarios to estimate the direct and indirect costs averted in 2016-2030. The same inputs and assumptions were used in estimating benefits. In addition, we also estimated the benefits of continuing current interventions by comparing the business as usual and reverse scenarios. Benefits were discounted at 3%.

For patients' productivity losses, we multiplied the number of malaria cases by the average number of days malaria patients are ill and the 2015 GDP per capita per day. We assumed that the productivity losses of caregivers were equal to those of patients.

To quantify the economic impact of premature deaths due to malaria, we used full income accounting to estimate VLYs lost. Full income approaches combine growth in national income with the value individuals place on increased life expectancy. By capturing the instrumental and intrinsic value of better health, full income measures provide a more accurate and complete picture of the benefits of health investments compared to traditional national income accounting, which only looks at GDP growth. In full income accounting, one VLY is the value people place in a one-year increase in life expectancy. VLYs vary by region and country, and based on estimates by the *Lancet Commission on Investing in Health*, one VLY in the East Asia & Pacific region is 2.2 times the GDP per capita at a 3% discount rate.

We assumed that 40 was the average age of death among malaria-related deaths, and that the life years lost to malaria was equal to the life expectancy at age 40 as reported in the United Nations World Population Prospects (2015 revision). We multiplied this number by the number of deaths and VLY to estimate the total economic impact of premature deaths.

The costs and benefits of elimination were compiled for each of the five GMS countries and added together to obtain the total cost and benefits in the region.

Return on investment

To calculate ROI of malaria elimination in 2016-2030, we subtracted the benefits of elimination in the region by the incremental cost of elimination and divided the resulting figure by the incremental cost of elimination. The ROI is interpreted as the economic return from every additional dollar spent on malaria above the counterfactual scenario. We calculated ROIs for both the resistance and baseline assumptions.

Financial landscape

We triangulated data from various sources to estimate past, present, and future financing for malaria. Historical figures (2000-2014) were retrieved from finance tracking work by the Institute of Health Metrics and Evaluation and the MEI (unpublished data) and was supplemented by data from the Global Fund and the World Malaria Report of the WHO. Financing data and the gaps from 2018-2020 was obtained from the RAI2E concept note.

Sensitivity analysis

We performed stochastic sensitivity analysis on the epidemiological and cost outputs of the transmission model. The minimum, median, and maximum malaria cases and deaths predicted by the model for each scenario were used to calculate the minimum, median, and maximum economic benefits.

For the costs, we assigned an uncertainty interval of +/- 25% on the value of the input costs used. Three hundred random samples were drawn, which generated a range of costs. From the range of costs generated, we determined the minimum, maximum, median, mean, and other measures (e.g., percentiles) which are presented in Annex 5.

Limitations

Many of the costs were estimates and may therefore not reflect the actual costs of elimination in the country. Several benefits of malaria elimination, which could not be valued accurately, were excluded from our calculations; thus, our benefits estimations are likely to be underestimates. The malaria transmission model used has inherent limitations, which may introduce uncertainty to the benefits estimations. The sensitivity analysis aims to address these issues.

Annex 5: Country level outputs

Transmission outputs

Figure A5-1: Afghanistan

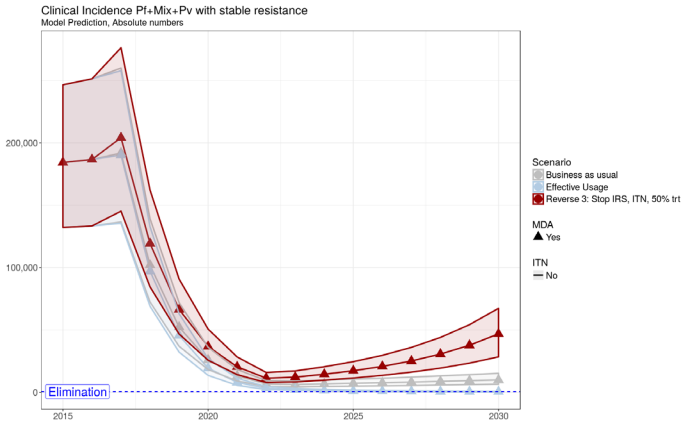


Figure A5-2: Bhutan

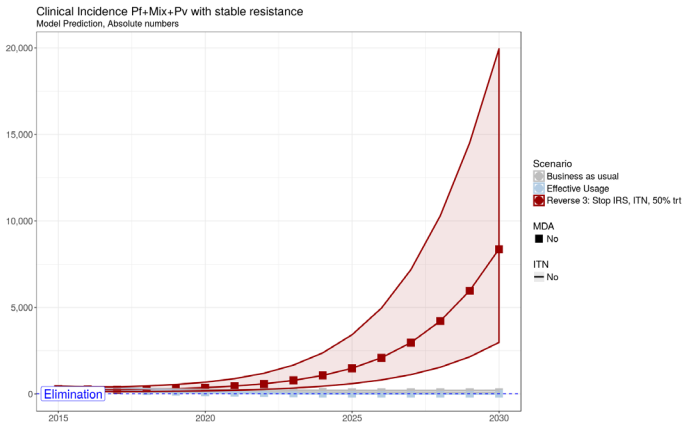


Figure A5-3: Bangladesh

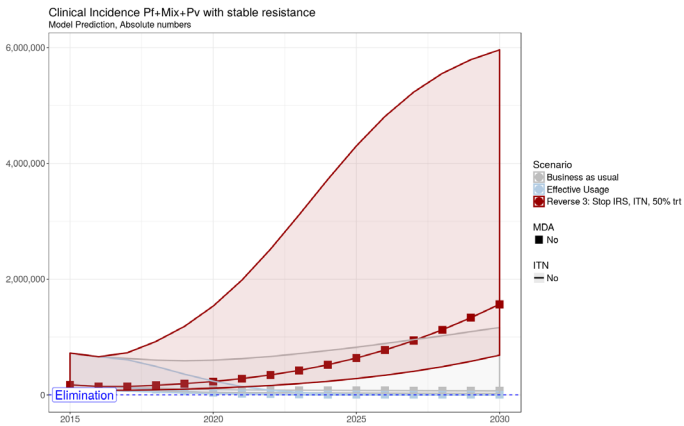


Figure A5-4: Cambodia

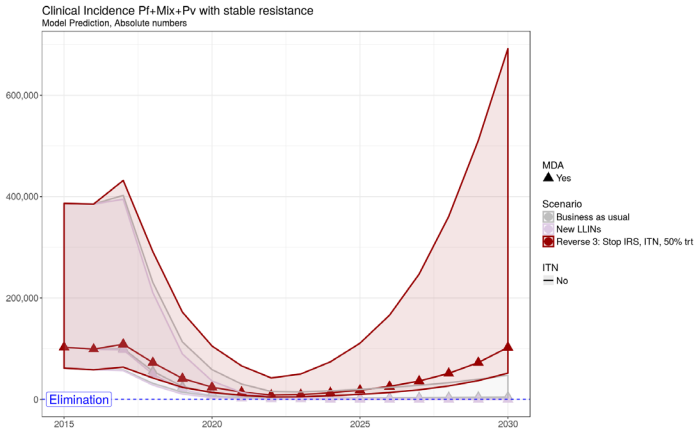


Figure A5-5: DPRK

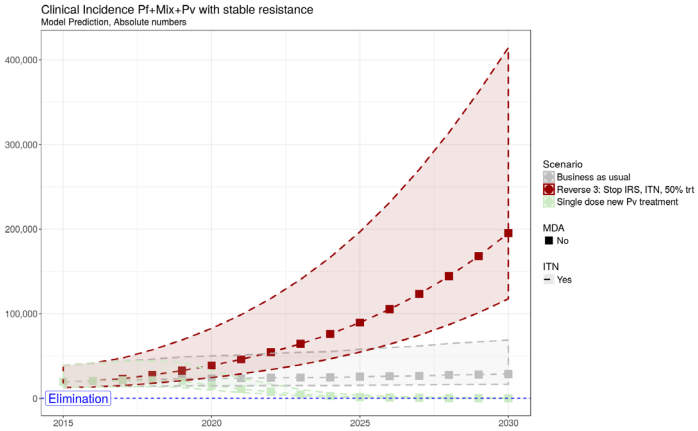


Figure A5-6: India

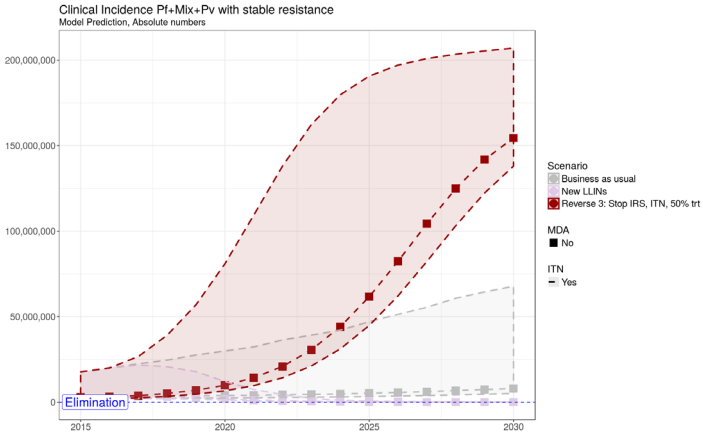


Figure A5-7: Indonesia

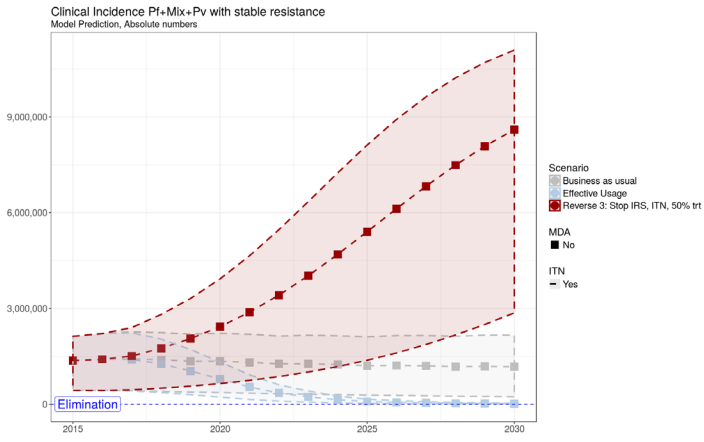


Figure A5-8: Lao PDR

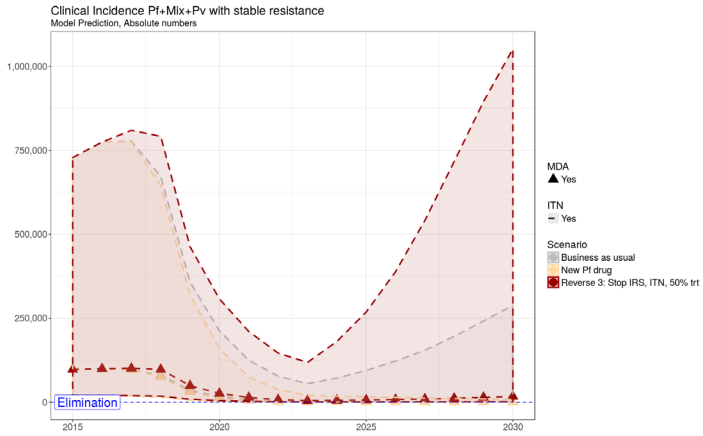


Figure A5-9: Malaysia

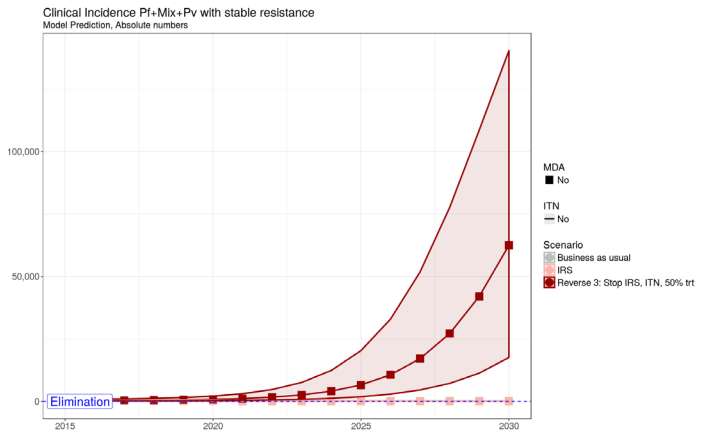


Figure A5-10: Myanmar

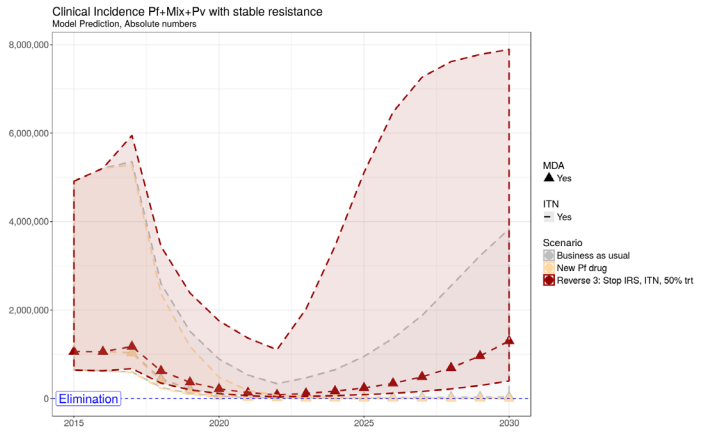


Figure A5-11: Nepal

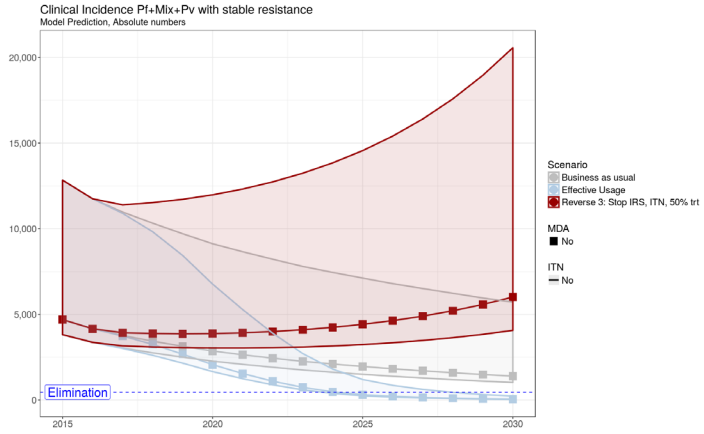


Figure A5-12: Philippines

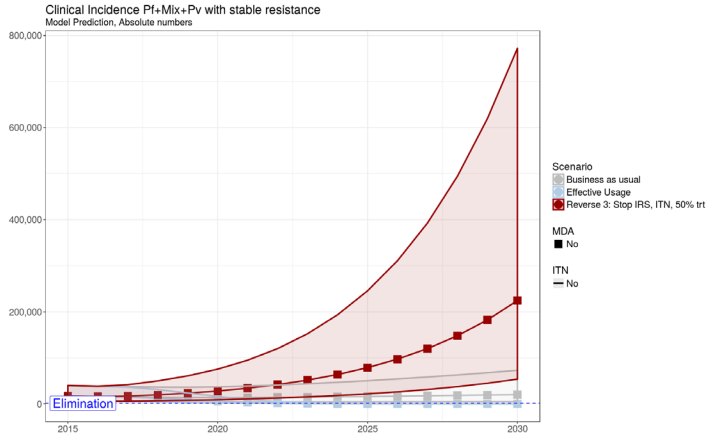


Figure A5-13:. Pakistan

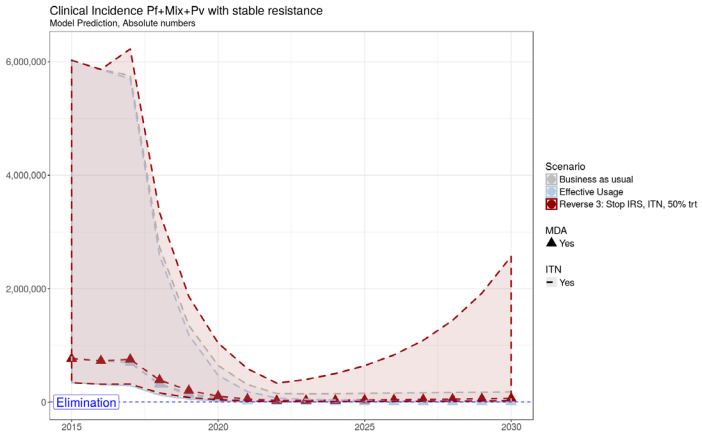


Figure A5-14: PNG

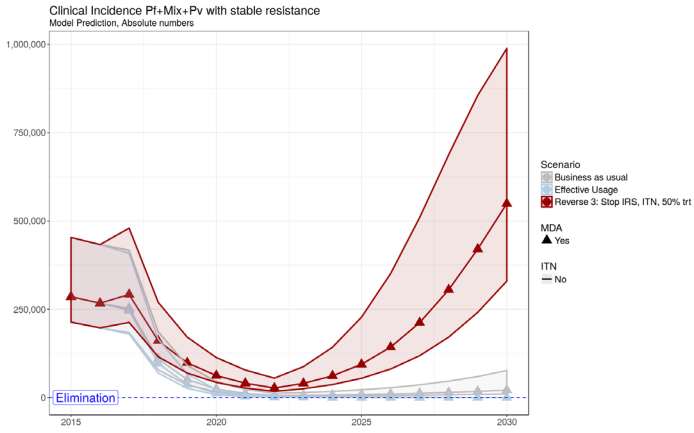


Figure A5-15: Solomon Islands

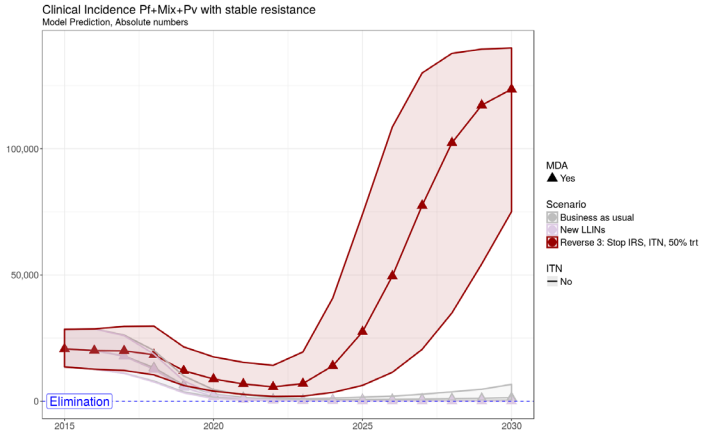


Figure A5-16: Thailand

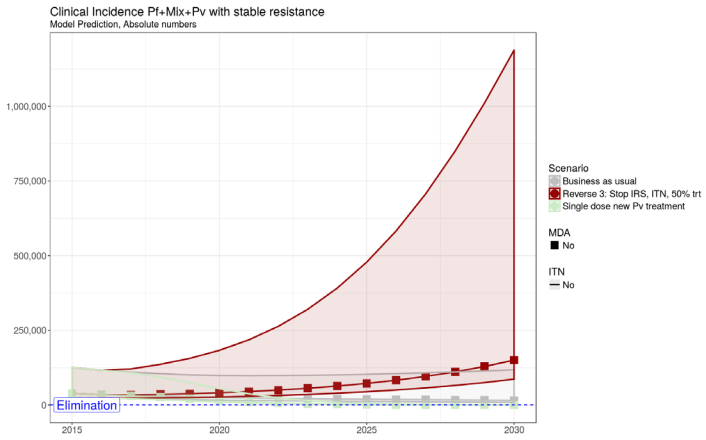


Figure A5-17: Timor-Leste

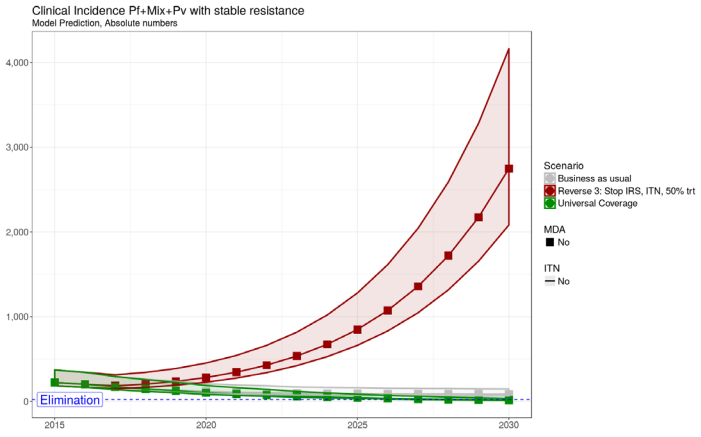


Figure A5-18: Vanuatu

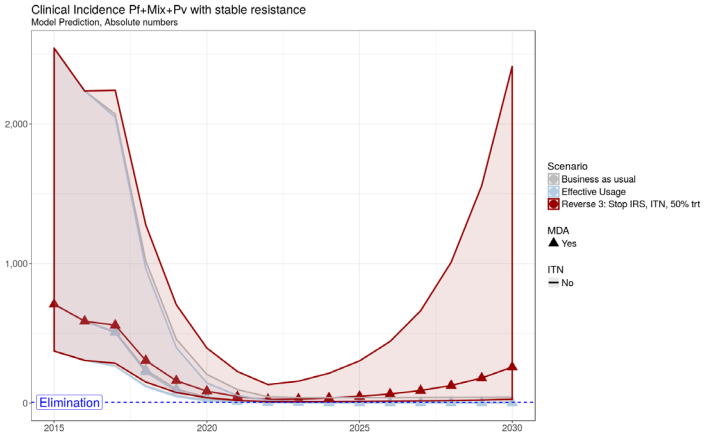
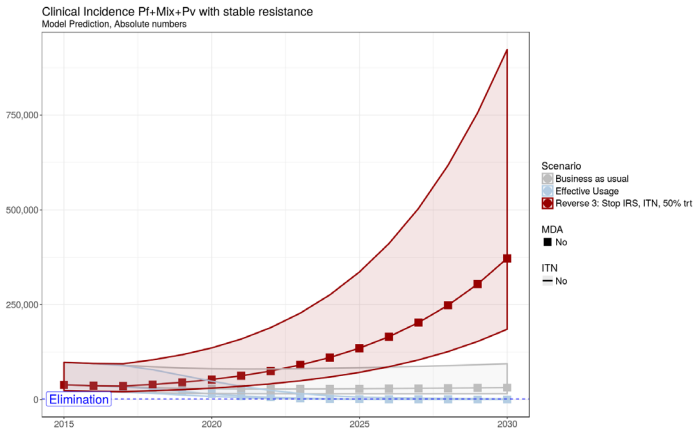


Figure A5-19: Viet Nam



Cost outputs

Figure A5-20:. Afghanistan

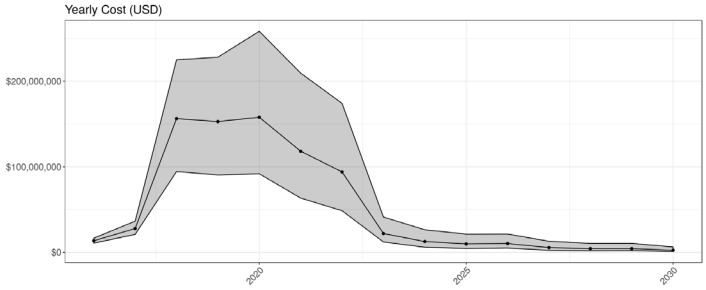


Figure A5-21: Bangladesh

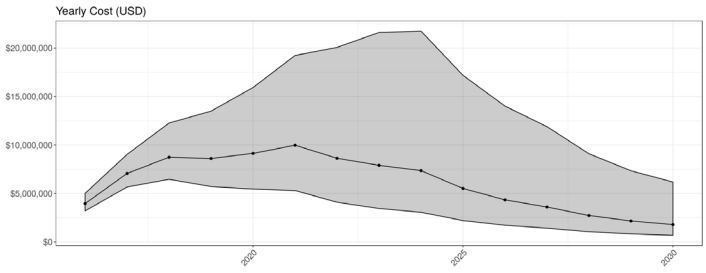


Figure A5-22: Bhutan

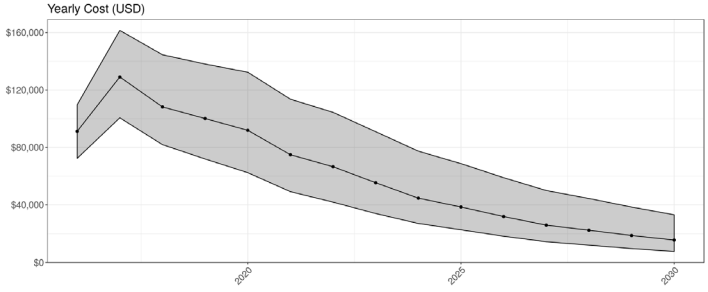


Figure A5-23: Cambodia

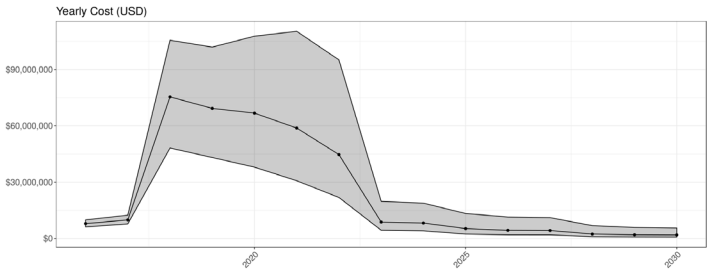


Figure A5-24: DPRK

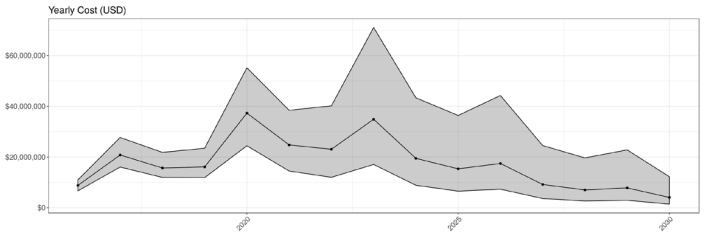


Figure A5-25: India

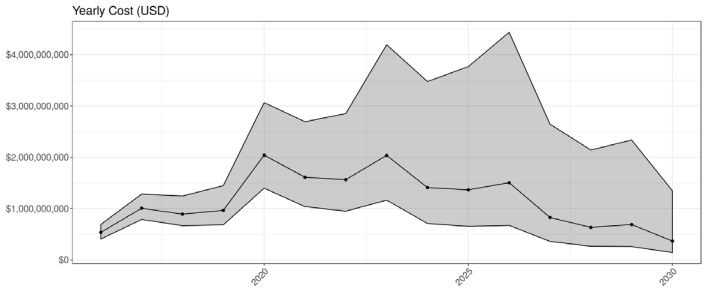


Figure A5-26: Indonesia

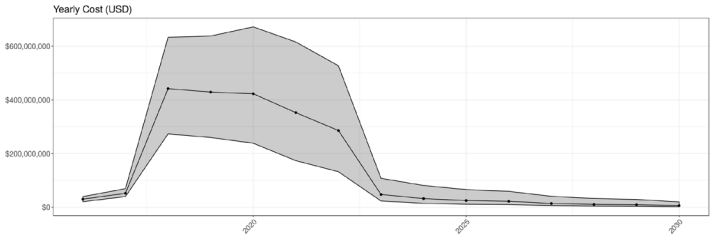


Figure A5-27: Lao PDR

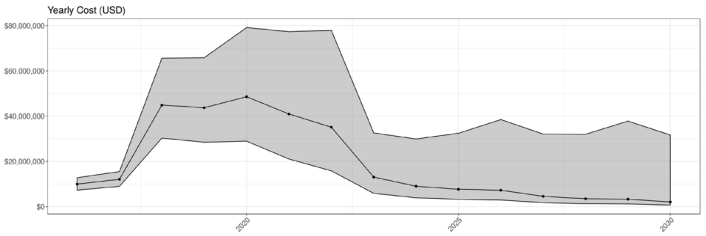


Figure A5-28: Malaysia

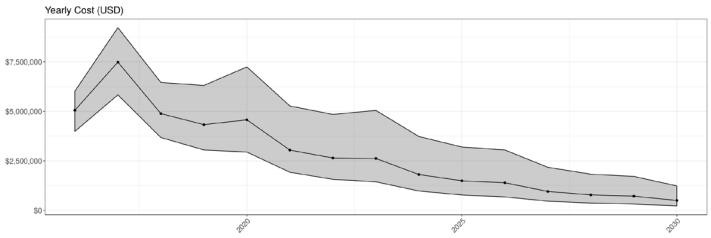


Figure A5-29: Myanmar

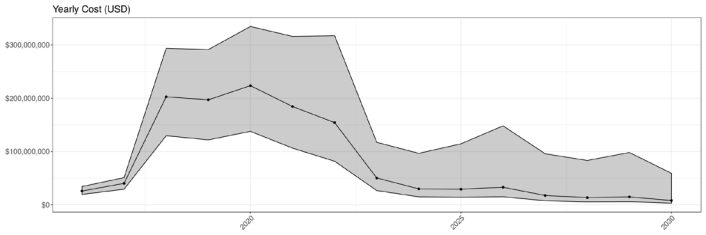


Figure A5-30: Nepal

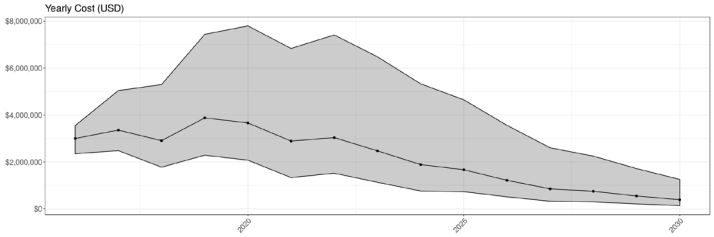


Figure A5-31: Pakistan

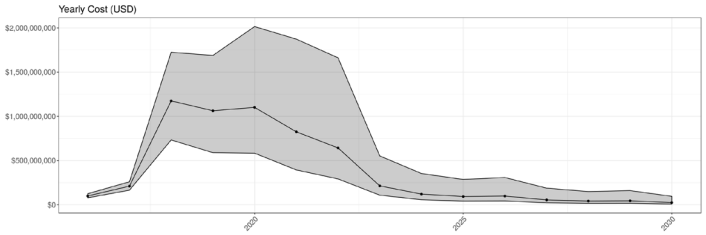


Figure A5-32: Philippines

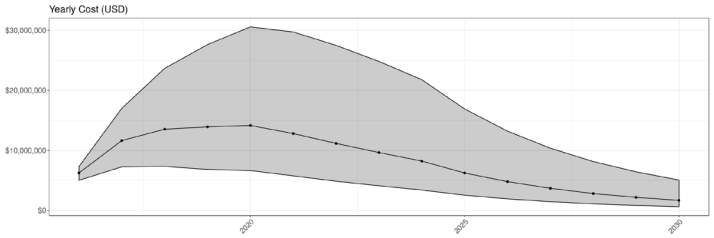


Figure A5-33: PNG

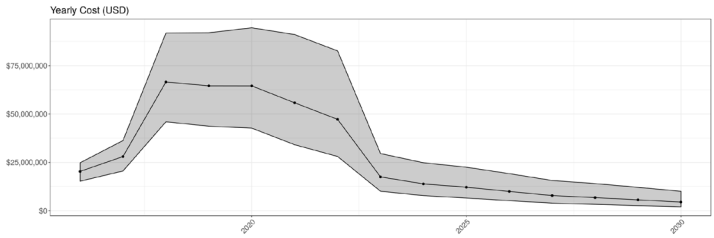


Figure A5-34: ROK

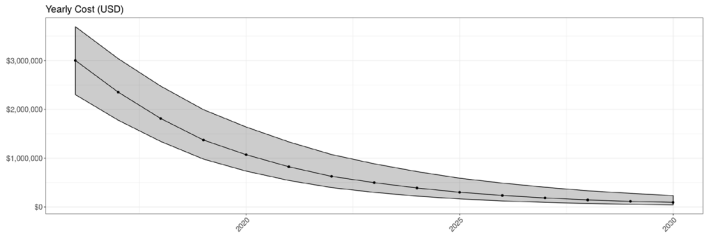


Figure A5-35:. Solomon Islands

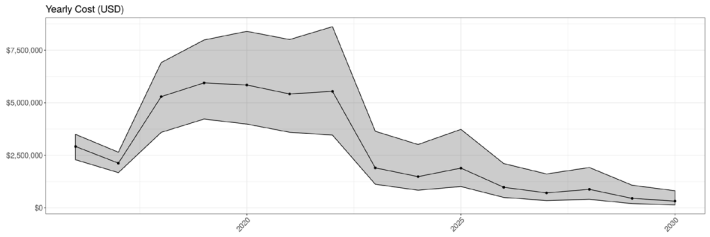


Figure A5-36: Thailand

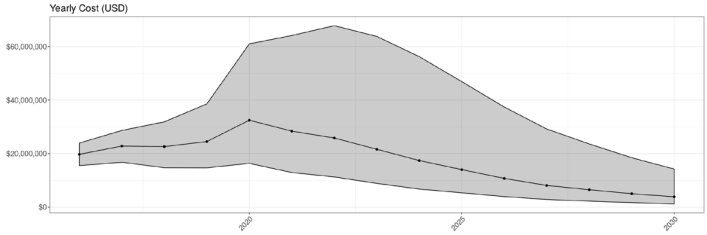


Figure A5-37: Timor-Leste

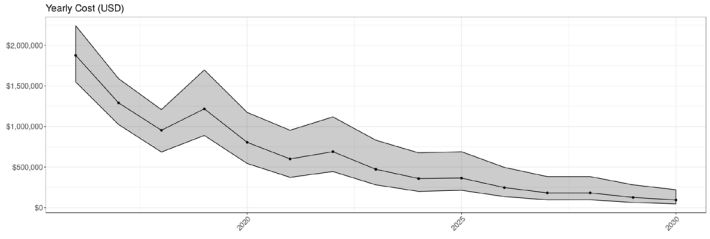


Figure A5-38: Vanuatu

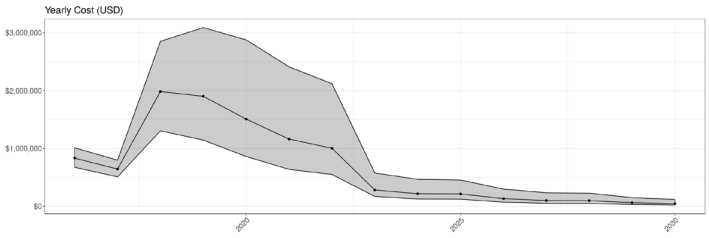
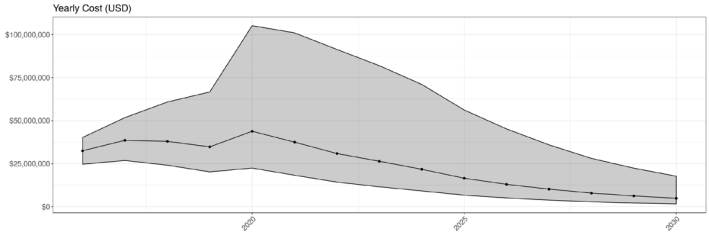


Figure A5-39: Viet Nam



Annex 6. Results of sensitivity analysis

Figure A6-1. Cost of elimination sensitivity analysis

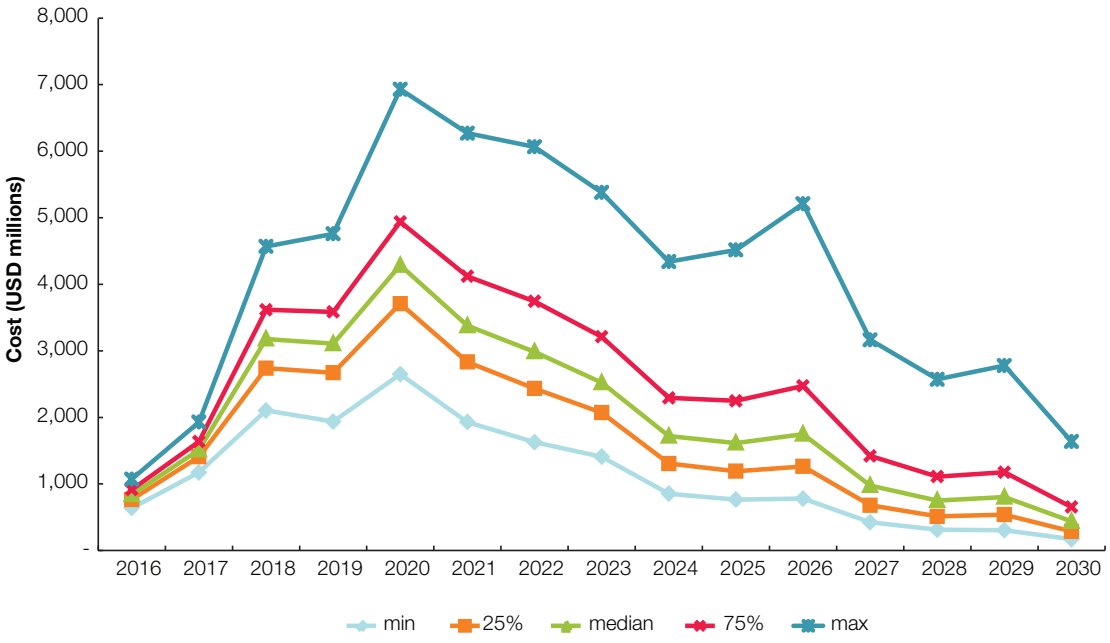


Figure A6-2. ROI estimates for malaria elimination using outputs of sensitivity analysis