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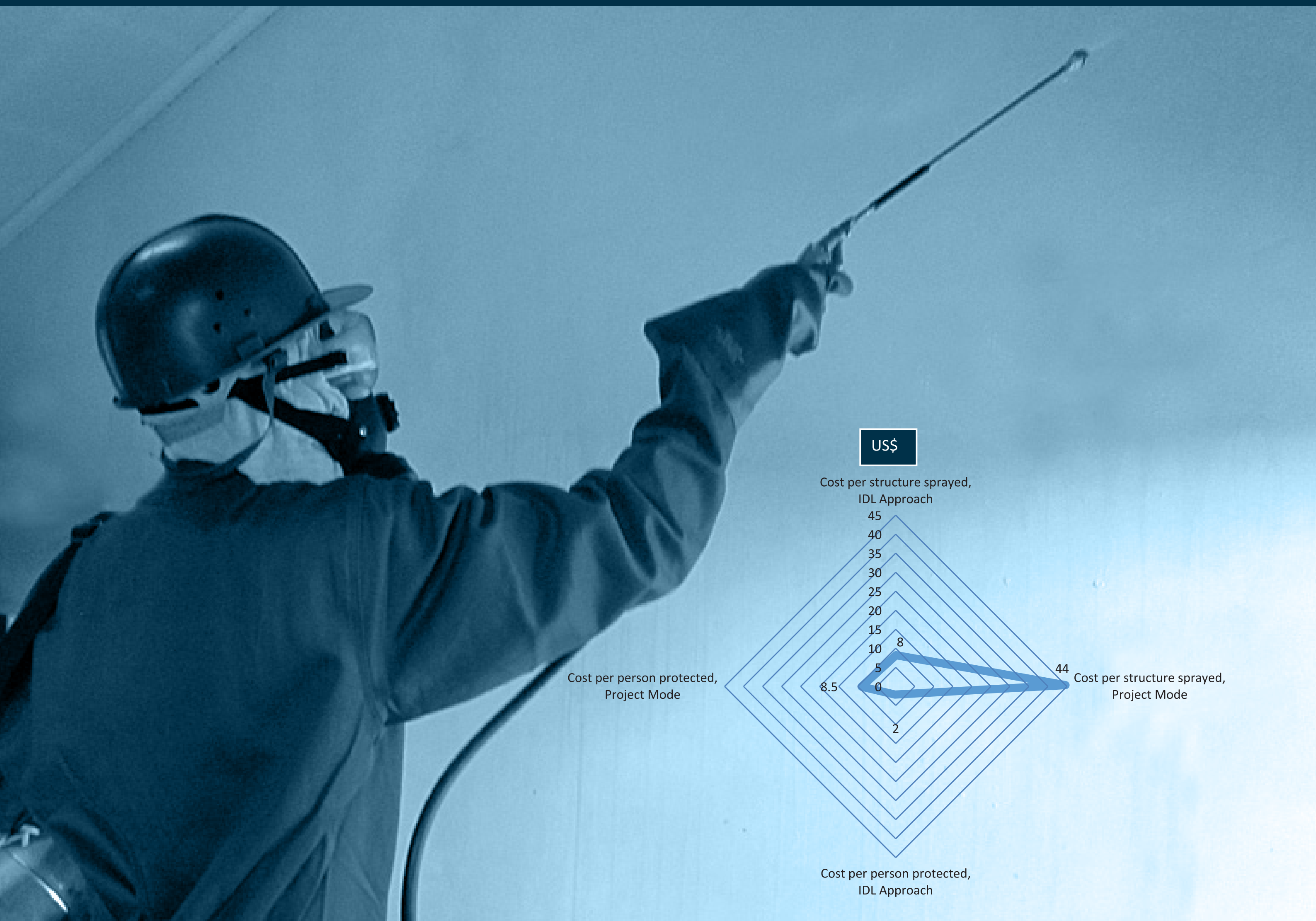
FINANCING INDOOR RESIDUAL SPRAYING FOR MALARIA PREVENTION IN UGANDA: OPTIONS FOR COST MINIMIZATION



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March 2019

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ABSTRACT

Uganda is the second largest contributor of total malaria cases in East and Southern Africa. Domestically, the burden of malaria is enormous and persistent (high morbidity, mortality, and economic loss). Among other strategies, the government has proposed large-scale Indoor Residual Spraying (IRS) intervention as a major component of current malaria control efforts, and recently, the political leadership voiced solidarity towards fighting malaria through the “Mass Action Against Malaria” campaign. This paper was motivated by the paucity of evidence on requisite financial resources to fund country-wide and phased IRS implementation. Additionally, given that the economy is highly resource constrained and is faced with innumerable competing development priorities and needs, it is imperative to explore low-cost options for IRS implementation. Therefore, this paper was aimed at analysing the costs of the country-wide roll out of IRS under different IRS delivery models, the cost implications of implementing IRS in a phased manner, and identifying cost-minimization strategies. We used the latest Uganda National Household Survey, market price data, and data from IRS pilot districts.

The results show that 235 billion shillings (approximately 63.5 million US$) is required to finance country-wide implementation of IRS using an Integrated District-Led (IDL) approach. The overall cost per structure and average cost per person protected are 28,000 shillings (8 US$) and 6,000 shillings (2 US$), respectively. The largest cost driver for an IRS programme is the insecticide, which accounts for about 66% -81% of the total cost depending on the mechanism of implementation. If IRS is implemented in a phased manner, starting with the most burdened eight sub-regions, a total financing of approximately 106.7 billion shillings (29 million US$) is required. The integrated district-led approach is associated with the least cost—it is about six times cheaper than the project-led approach. The estimated annual cost of implementing LLINs is comparable to the IRS cost; however, IRS is the optimal option. IRS is also cheaper than malaria case management; the annual cost of case management more than doubles that of IRS.

Accordingly, our findings suggest that more emphasis or investments in malaria prevention using IRS is a less costly venture for the government to undertake and presents cost-saving opportunities in the fight against malaria; hence, it is a seemingly more sustainable measure. The government should utilize existing District Local Government and community-based structures, as well as spray logistics in IRS pilot districts, to minimize the cost of IRS implementation. Some of the specific IRS low-cost strategies for policy consideration include the following: using existing spray logistics on a rotational basis; using locally available human resources as SOPs; incorporating IRS Behavioural Change Communication (BCC) into the immunization BCC; using subsidies or fiscal incentives to manufacture insecticides domestically; sourcing insecticides at competitive rates; financing IRS domestically; and using a private-sector model of service delivery combined with a public health approach.

1.0 INTRODUCTION

Despite being a largely preventable and treatable disease, malaria is responsible for approximately 216 million cases and 445,000 deaths globally (WHO, 2017)[1]. Africa alone accounts for almost 90% of the global malaria burden, and the progress against malaria on the continent is reported to have stalled (ibid). Although Uganda has registered gains in malaria reduction efforts, having reduced the malaria prevalence from 45–19% in 2014/15 (UBOS, 2015), it contributes disproportionately to the malaria burden in Africa. It is the second highest contributor of the total malaria cases in East and Southern Africa, with a contribution of 17% (WHO, 2017).

Locally, malaria remains the leading cause of mortality and morbidity. It accounts for 30–50% of outpatient visits, 15–20% of hospital admissions and up to 20% of all hospital deaths (MoH, 2015). With 2,257 thousands of years of life lost due to malaria between 1990 and 2010, malaria has accounted for 14.7% of total years of life lost in Uganda over the same period (ibid). Whilst the malaria prevalence is highest among children under five years and pregnant women, most of the population is at risk because malaria is endemic in approximately 95% of the country, affecting over 90% of the population. The remaining 5% are epidemic prone (MoH, 2015). Malaria not only negatively impacts an individual's health but also imposes an economic burden on individuals and households through health care costs and the entire economy through the loss of workdays and decreased productivity (MoH, 2015). For example, an episode of malaria is, on average, associated with the loss of 8.4 productive days in Uganda and 6, 10.79, and 4.8 days in Rwanda, Ghana, and Nigeria, respectively (Okorosobo *et al*., 2011), in turn retarding economic growth. The socio-economic impact of malaria includes increased out-of-pocket expenditure for consultation fees, drugs, transport and subsistence at (often) distant health facilities. These costs are estimated to be between USD 0.41 and USD 3.88 per person per month equivalent to USD 1.88 and USD 26 per household[2]. A single occurrence of malaria costs a household, on average, 9 USD or about 3% of yearly earnings (MoH, 2014)[3].

To reduce the burden of malaria, the Ministry of Health (MoH) has implemented several malaria control measures. However, vector-control methods, mainly using Long-Lasting Insecticide-Treated Nets (LLINs)[4] and Indoor Residual Spraying (IRS) remain the cornerstone of Uganda's efforts to control malaria. Other malaria control initiatives include Larval Source Management, Intermittent Preventive Treatment (IPT) for pregnant women, and case management through the use of artemisinin-based combination therapy (ACTs) (MoH, 2014). Despite the re-introduction of IRS in 2006, the use of LLINs has been largely promoted as the primary intervention for malaria vector control in Uganda for the last two decades. The national coverage for LLINs currently stands at 62%[5] against a mere 4.9% for IRS (UBOS and ICF International, 2015). Unlike LLINs, IRS has received relatively little attention and has not been implemented to scale except in endemic areas of Northern Uganda. The relative cost of IRS versus the insecticide-treated nets has, in part, informed the slow roll out of IRS. Implementing IRS has been perceived to be

1 World Malaria Report 2017

2 Kolaczinski, K. Kolaczinski, D. Kyabayinze, D. Strachan, M. Temperley, N. Wijayanandana and A. Kilian (2010), "Costs and effects of two public sector delivery channel for longlasting insecticide nets in Uganda", Malaria Journal, 9(1): 1-16.

3 Malaria Reduction Strategic Plan 2014-2020 (UMRSP)

4 One significant shift from past practice is that since 2002, long-lasting insecticide-treated nets (LLINs), which are designed to protect people for up to 3-5 years of use, are now being prioritized over ordinary ITNs, which have a far shorter duration of insecticidal activity.

5 This represents households with at least one LLIN for every two persons

very expensive[6] based on estimates from project-based implementation mechanisms (MoH, 2017). However, as evidenced in the current malaria reduction strategic plan, there is renewed interest in implementing large-scale IRS programmes as a major component of the current malaria control efforts. The government plans to roll out IRS to 55 malaria endemic districts by 2020. Additionally, the political leadership of the country has shown a commitment towards fighting malaria. His Excellency, the president of Uganda, recently (April 2018) launched the "Kick Malaria out of Uganda" campaign through the Mass Action Against Malaria (MAAM) Initiative. However, there are important considerations that must be considered as the country prepares to scale up IRS. Particularly, sufficient resources must be mobilized, and, given resource constraints, cost-saving delivery channels should be used. In view of the proposed IRS roll out, a study to estimate the required financial resources becomes imperative.

Therefore, the purpose of this study was to estimate the cost for a country-wide roll out of IRS using a district-led approach of implementation, provide cost implications of implementing IRS in a phased manner, and identify low-cost (cost minimization) strategies for implementing IRS. Likewise, the study analysed the costs for different IRS delivery channels— project-based delivery versus integrated district models—and assessed the financial sustainability or affordability of IRS to the government. We also performed a comparative analysis of the costs of IRS using another vector control method (LLINs) and other malaria interventions such as case management.

The paper is structured as follows: Section 1 provides a brief overview of the malaria situation and control in Uganda. Section 2 presents the prevalence, coverage of current vector control interventions, and evidence of the effectiveness of malaria control interventions—specifically IRS. Section 3 highlights the study methods, and section 4 focuses on the results for cost estimations for malaria prevention interventions with particular emphasis on IRS. Section 5 concludes with recommendations.

6 "IRS is a very expensive and labour intensive intervention that without huge upfront investment, is nearly impossible to start and sustain" (page 24 UMRSP mid-term review report, 2017)

2.0 MALARIA SITUATION: PREVALENCE, INTERVENTIONS AND EFFICACY

2.1 Malaria prevalence

As mentioned earlier, there is stable, perennial malaria transmission in 90-95% of the country with the rest having high potential for epidemics. The MoH estimates that, in a given year, at least 16 million cases of malaria are reported in the country (MoH, 2014)[7], and the disease is common among children aged 5 years and younger and pregnant women. *Plasmodium falciparum* remains the major species responsible for most malaria cases. Table 1 shows the proportion of children aged 0–59 months that tested positive for malaria using microscopy testing in the 2009 and 2014 Malaria Indicator Surveys (MIS). The results showed that malaria prevalence is on a downward trend, having been reduced by 15 percentage points from 42% to 19% over a five-year period (2009-2014/15). Using a rapid diagnostic test (RDT), the prevalence of malaria among children aged 0–59 months was reported as 30%[8] (UBOS and ICF International, 2015). The highest reduction in the prevalence of malaria was registered in the Mid North—by 3-fold from 63 in 2009 to 20 in 2014/15. This reduction may be attributed to the use of IRS between 2009 and 2014/15; from a pilot in

7 MoH 2014. The Uganda Malaria Reduction strategic plan

8 The prevalence is higher with RDT than microscopy because RDT detects antigens to malaria parasites that can be present in blood for up to several weeks after successful treatment of the infection. By contrast, microscopy detects the actual parasite.

Table 1: **Malaria prevalence among children aged 5 years and younger (%)**

	2009	2014/15
Central 1	39	11
Central 2	51	24
East Central	**56**	36
Kampala	4.9	<1
Mid North	**63**	**20**
Mid West	43	18
Mid Eastern	38	13
North East	40	27
South Western	12	4
West Nile	46	28
Total	**42**	**19**

Source: Compiled using UBoS, MIS 2009 and 2014/15

Kabale district in 2006, IRS was extended to 10 endemic districts in Northern Uganda between 2008 and 2009. However, the latest data from UDHS (2016) showed that the Karamoja (North East), Mid North, and Lango sub-regions are the three top sub-regions with the highest malaria burden.

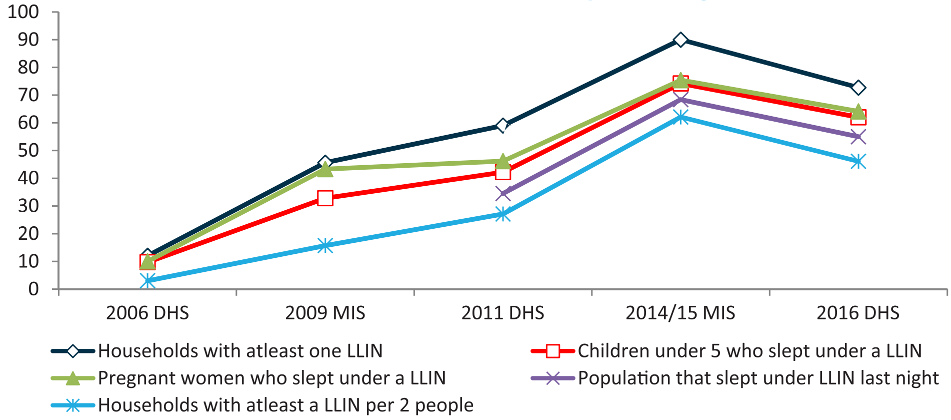
2.2 Coverage of vector control interventions

As noted earlier, Uganda's strategy for malaria prevention and control is based on three vector control methods – use of Long Lasting Insecticide Treated mosquito Nets (LLINs), Indoor Residual Spraying (IRS) and larval source management. This subsection elaborates the extent of coverage of IRS and LLINs because the two methods account for the highest investment in malaria vector control.

Over the last 10 years, the usage of LLINs has greatly improved, except for a decline reported in 2016. Figure 1 shows that households with at least one net per household increased from 12% in 2006 to 90% in 2014/15, before declining to 72.7% in 2016. This coverage was below the UMRSP target of 85% by 2017. Although net ownership (based on at least one LLIN per household) is relatively high, it does not meet the universal access to and use of the LLINs policy, actualized by one net per 2 persons in a household. Less than half of the households reported (46 percent) to have at least one net for every 2 adults in the household (Figure 1). Mass distribution campaigns aimed at achieving high and equitable coverage have commonly been used to boost universal coverage. With the recent mass distribution of LLINs in the FY 2017/18, the coverage could have improved from the one reported in Figure 1 below.

The usage of nets is highest among pregnant women, followed by children younger than 5 years of age. This is not surprising given the high malaria incidence among children and pregnant women coupled with various net distribution interventions targeting these two population categories. For children aged five years and younger, 62% reported having slept under a mosquito net the night before the survey (a decrease of approximately 12% from 2014/15). Similarly, approximately 64% of pregnant women reported having slept under an LLIN the night before the survey (a reduction of 11% from 2014/15) (Figure 1). Only 55% of the general population reported to have used an LLIN the night preceding the survey. This implies that despite the various campaigns and mass distribution campaigns undertaken, consistent usage of nets remains a challenge. On average, on any given night, over 25% of mosquito nets are not used (UBOS and ICF International, 2015). Yet, the effectiveness of nets relies entirely on the extent to which the

Figure 1: **Trend in LLIN ownership and usage (%)**

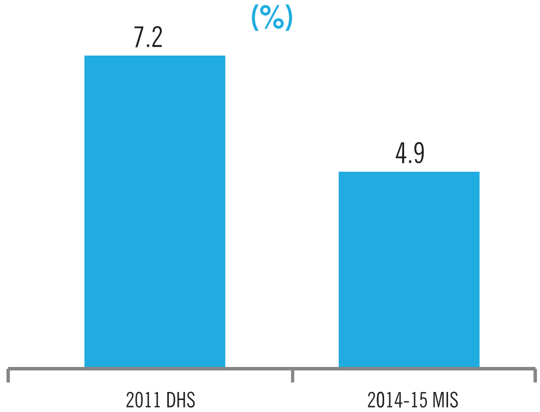


Source: Author's computation using MIS and UDHS, various years

owned nets are put to use. Some of the reasons why nets are not used range from 'not yet hung' and 'too hot', among others (UBOS and ICF International, 2015).

Alongside the promotion of access and usage of LLINs, the Malaria Control Program uses IRS as a complementary intervention, particularly in highly endemic districts of Northern and Eastern Uganda. The UMRSP targeted to scale up IRS in 50 contiguous districts from the initial 10 districts at baseline in 2015. However, in 2014, the original 10 districts were discontinued and the programme moved to 14 new districts in Northern and Eastern Uganda. This is far below the UMRSP target of 25 districts envisaged by 2017 (MoH, 2015). Figure 2 shows the extent of IRS coverage by households; about 7.2% of households reported having sprayed with IRS in the 12 months preceding the survey, a proportion that declined to 4.9% in 2014/15 (Figure 2). Since IRS is implemented in a targeted manner, regional variations in coverage are inevitable. For instance, according to 2011 UDHS statistics, although the national IRS coverage was 7.2 percent, the North (excluding West Nile and Karamoja) had a coverage of 66% (UBoS and Macro, 2011). The 2015 WHO operational manual for IRS suggests that, for IRS to be effective, there must be high coverage (usually 85%) of all structures that are potential resting places to obtain the mass effect on the vector population (WHO, 2015). Given that malaria is endemic in 95% of Uganda, the current scale of IRS coverage will not be able to rapidly interrupt malaria transmission to reduce malaria cases.

Figure 2: **Percentage of households sprayed with IRS in the last 12 months preceding the survey (%)**



Source: Author's computation using UDHS 2011 and MIS 2014/15

2.3 Evidence on IRS efficacy

The decision to use IRS should be guided by several factors including: entomological, epidemiological, ecological, environmental, demographic and socio-economic and heath service factors (WHO, 2015). When carried out correctly, IRS is a powerful intervention to rapidly reduce adult mosquito vector density and longevity, thereby reducing malaria transmission. IRS is most effective against indoor-feeding (endophagic) and indoor-resting (endophilic) vectors (ibid). The common malaria vectors in Uganda are *Anpholes gambie s.1* and

An. funestus; they are mainly endophagic and endophilic, making IRS a viable vector-control strategy.

There is relatively sufficient evidence on the effectiveness of IRS in malaria control in Uganda in both high- and low-transmission areas. In high-transmission intensity areas of Northern Uganda, Kigozi et al., (2012), Steinhardt et al., (2013), and Tukei et al., (2017) provide evidence on the effect of IRS on malaria morbidity in Northern Uganda. Steinhardt et al., (2013) conducted a cross-sectional household survey in high-transmission northern Uganda in two districts (Pader and Apac) previously sprayed with pyrethroids and at least one round of carbamates and in one contiguous district (Lira) that was not sprayed. The parasitaemia prevalence among children < 5 years of age was significantly lower in the two IRS districts compared with that in the non-sprayed district (37.0% and 16.7% versus 49.8%). Similarly, Tukei et al., (2017)[9] and Kigozi et al., (2012) found that IRS was associated with a significant reduction in the malaria morbidity in areas of high-transmission intensity in Northern Uganda.

There is also evidence that IRS is effective in low-transmission areas; a study from the low-transmission Kanungu district provides more support on the effectiveness of IRS. Based on individual data collected from one health facility within 8 months before and 16 months after IRS, the study found a consistent decrease in the proportion of patients diagnosed with clinical malaria after IRS. The incidence of malaria reduced from 52% to 26% for children younger than 5 years and from 36% to 23% for patients older than 5 years of age (Bukirwa et al., 2009). However, this effect was reported to wane in the subsequent 12 months, signifying a need for routine spraying to interrupt malaria transmission.

9 Assessing the effect of IRS on Malaria morbidity in Northern Uganda: A before and after study

Box 1: How IRS works to prevent malaria

"The effectiveness of IRS as a malaria control intervention arises from the fact that many important malaria vectors are endophilic (tend to rest in doors). That is, when searching for blood meals they enter human habitations or animal shelters where they rest on the walls, ceilings and other interior surfaces before or after feeding on the residents. When a vector comes into contact with a sprayed surface, it absorbs a lethal dose of insecticide, thereby reducing its lifespan. This results in a progressive decline in vector density and longevity, especially among older female mosquitoes, and a reduction in overall vectorial capacity, thereby contributing to a reduction in malaria transmission".

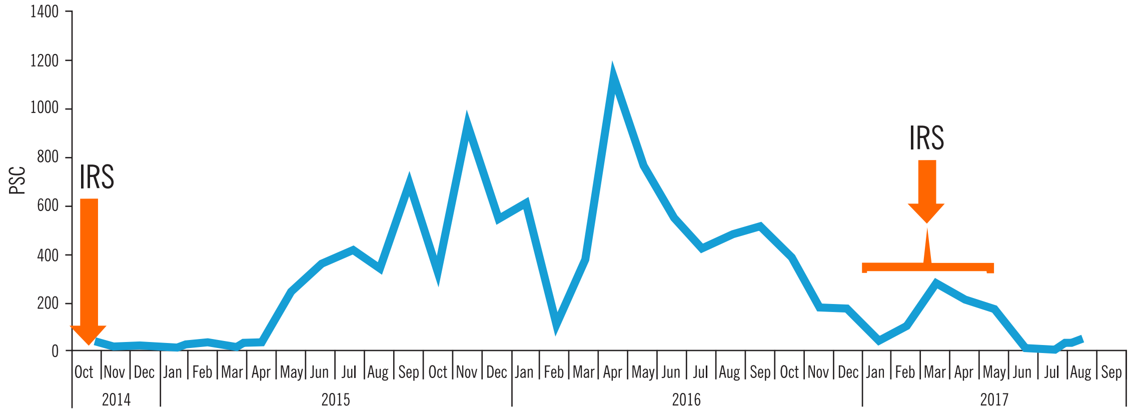
Source: WHO 2015 (page 4)

Figure 3 below provides more evidence on the impact of IRS on mosquito indoor resting density. There seems to be a clear negative correlation between IRS and the mosquito indoor resting density. The low densities (almost zero) in 2014 and 2017 are associated with periods when the study districts were sprayed with IRS while the increase in 2015/16 was observed when IRS was discontinued (MoH, 2017). The increases in resting densities were positively correlated with increased malaria cases in the five districts. IRS was only re-introduced in some of the former IRS districts in December 2016 as an epidemic response measure, resulting in a 2017 decline in densities (MoH, 2017).

A systematic review of district-level monthly data from the District Health Information System 2 (DHIS 2) covering 2012-2014 and that from April-June 2015 showed increased positivity rates (184% increase) compared with the baseline period of 2012-2014. The most affected districts were the former IRS districts that had transitioned from IRS to universal coverage of LLINs and improved case management by 2014 (USAID, 2018)[10]. These

10 USAID Presidential Malaria Initiative Uganda. Malaria operational plan FY 2018

Figure 3: **Mosquito indoor resting density measured using Pyrethrum spray catches in five districts in northern Uganda (2014-2017).**



Source: MoH, 2015 (UMRSP Midterm Review)

findings further affirm the effectiveness of IRS in the malaria reduction agenda.

Moreover, there is evidence that co-application (application of ITNs and IRS) confers greater protective benefits than either ITNs or IRS when used alone. Based on nationally representative survey data from 17 countries in South Africa, Fullman et al., (2013) found that living in households with both ITNs and IRS was associated with a significant risk reduction against parasitaemia in medium- and high-transmission areas.

2.4 IRS and insecticide resistance

Despite the reported effectiveness of IRS, concerns of increased resistance to some insecticides have emerged. Four classes of insecticides have been tested for resistance in Uganda—pyrethroids, organochlorines (DDT), carbamates (Bendiocarb), and organophosphates (Malathion, and Fenitrothion). The results from sentinel sites have indicated the development of resistance to pyrethroids and organochlorines. For example, resistance to DDT and pyrethroids has been documented through studies conducted in central and eastern Uganda (Morgan et al., 2010; Ramphul, 2009; Verhaeghen, 2010). Using different types of insecticides for different spray rounds, evaluation evidence from the Apac district showed that the odds of malaria were much greater after the rounds where a carbamate class (bendiocarb) of insecticide was used (Kigozi et al., 2012).

With the emergence of insecticide resistance, the choice and type of insecticide used during IRS implementation becomes a key determinant of effectiveness. Consequently, the choice of insecticide class in Uganda has evolved from DDT to pyrethroids to carbamates and recently to organophosphates [pirimiphos-methyl (Actellic)]. In this study, we used Actellic to analyse IRS-related costs, given the successful pilot based on Actellic in Northern Uganda. However, this switch of insecticides is associated with other challenges. According to the UMRSP, organophosphates and carbamates are much more expensive with more stringent environmental requirements (MoH, 2017). Additionally, the resistance to pyrethroids, the only class of insecticides that is currently being used on insecticide-treated nets (WHO, 2015), may further undermine the effectiveness of LLINs as a malaria-prevention strategy. To deal with the challenges of insecticide resistance and determine the appropriate selection of insecticides to mitigate or delay the further development of resistance, the WHO and its partners have developed a Global Plan for Insecticide Resistance Management in malaria vectors (GPIRM). The plan calls for the building of capacity and systems for basic epidemiological and entomological monitoring, including bioassays for insecticide susceptibility of the local vector population (WHO, 2015).

3.0 METHODOLOGY

3.1 Data sources

The data used for the costing analysis were primarily of secondary nature, obtained from existing databases. This was complemented by primary data from three district-led IRS pilot districts in Northern Uganda. The secondary data were in four parts:

(1) Insecticide pricing data. Data on pricing was obtained from one of the main manufacturers of IRS insecticides—Merck KGaA, Darmstadt, formerly Sigma-Aldrich[11]; Merck KGaA, Darmstadt is one of the suppliers recommended by the WHO. The insecticide pricing data obtained from Merck KGaA, Darmstadt (Sigma-Aldrich) were verified using price data from the East African/Ugandan-based agent for Sigma-Aldrich (i.e., Kobian Scientific, Uganda). Kobian Scientific was contacted and supplied the price data. The insecticide unit price data were also corroborated using pilot evidence/data from the IRS pilot districts in Northern Uganda, as well as the market price obtained from a market survey undertaken in Kampala.

(2) Structures for spraying. The study used the latest round of the Uganda National Household Survey (UNHS 2016/17) to estimate structures/houses at the national and sub-regional levels. UNHS is a nationally representative survey implemented by the Uganda Bureau of Statistics (UBOS) and covers more than 15,000 households. Using this data, spray structures were estimated for different regions and sub-regions in the country, based on sub-regional classification by UBOS. Survey weights were applied to compute estimates for the entire population.

(3) Cost data for IRS implementation based on a project-led approach, LLINs and malaria case management cost. For the IRS project-led approach, unit cost data were obtained from the Uganda Malaria Reduction Strategic Plan (UMRSP 2014/15 – 2019/20), which is based on project mode of implementation. The data for LLIN cost were from the mid-term review of the UMRSP 2014/15–2019/20. The data on case management were based on the malaria incidence, population, and unit cost data that were obtained from the Annual Health Sector Performance Report, population estimates from UBOS, and UMRSP 2014/15–2019/20. Finally, the data on the indirect[12] cost of malaria were from the malaria economic burden analysis by Okorosobo et al., (2011), which shows that the indirect cost to households for an episode of malaria in Uganda was 7.74 US$.

(4) Data on spray commodities, spray operations, and labour (human resources). The data on the required spray commodities were obtained from the IRS pilot districts in Northern Uganda, complemented by the market price data for the spray logistics.

Specifically, the data on IRS operations based on a district-led approach of implementation were collected from 3 districts of Northern Uganda where IRS was piloted. The data were obtained through Key Informant Interviews (KIIs) and programme document review. The sampled districts were those where the district-led IRS pilot programme was implemented (i.e., Agago, Kole, Gulu). Kole district was selected because it is a highly endemic district; Gulu was selected because it has more experience

11 https://www.sigmaaldrich.com/analytical-chromatography/analytical-products.html?TablePage=18500182

12 This involves quantifying, in monetary terms, the opportunity cost of the time spent by households seeking treatment from healthcare providers. It also includes, during the days of complete incapacitation and period of convalescence, the productive time that was lost by the malaria patients, their caretakers and substitute labourers (Okorosobo et al., 2011).

in implementing IRS using both district-led and project-led approaches. Finally, Agago was selected due to its experience as a newly created district (i.e., implementing IRS for the first time).

3.2 IRS intervention cost categories

The relevant cost categories of IRS programme implementation, including insecticide procurement, were identified. The analysis considered the different cost categories for IRS intervention, as per the President's Malaria Initiative (PMI) IRS programming, as well as IRS pilot evidence from Northern Uganda. These include the following:

(a) Procurement of insecticides (chemicals). This captures the quantity and cost of insecticides required based on their current unit prices.

(b) Spray commodities (logistics). These are equipment supplies such as spray pumps (sprayers), protective equipment such as respirators, gloves, overalls, and boots.

(c) Spray operations: This includes costs associated with transportation, warehousing, training (costs for training the spray teams comprised, for example, Spray Operators - SOPs and supervisors, among others), environmental compliance (i.e., the use of soak pits or waste management by collecting and washing empty bottles after spraying), spray planning, local administration or supervision, and monitoring and evaluation among others.

(d) Human resources (labour). This comprises labour-related costs such as those for Spray Operators (SOPs) and includes temporary labour and costs related to the supervision of IRS implementation.

(e) Behavioural Change Communication (BCC). This involves costs related to Information, Education and Communication (IEC) and includes spray campaign and/or community sensitization.

(f) Miscellaneous costs. Based on the World Health Organization (WHO) quantification approach, we estimate a 10% buffer stock (on the required volume of insecticide) and computed an extra 10% of operational costs to accommodate miscellaneous expenditure.

3.3 Estimation of insecticide requirement

We use WHO's estimation strategy for IRS insecticide quantification (WHO, 2015)[13] (see equation 1). According to the estimation strategy, the computation for a spray round considers the following variables: the spray structures (houses or households to be sprayed), average sprayable surface, concentration of active insecticide ingredients in the insecticide formulation, and insecticide application rate.

$$W_{irs} = \left(\frac{AS * D * 100}{C}\right) * H \qquad (1)$$

where W is the total quantity of IRS insecticide needed (in grammes or kilogrammes), and AS is the average sprayable surface per house in square metres and is the product of the number of rooms and room size. Given that the room size is not captured in the UNHS data, we used the recommended average size of a habitable room of 7.5 M^2 (UBOS – UNHS, 2016/17) to estimate the average sprayable surface. The UNHS data also capture only the number of rooms for sleeping, but not the total number of rooms of each house. Given this data limitation, the quantification based on the number of rooms captured in the UNHS data only provides the insecticide volume required to spray sleeping rooms.

13 WHO (2015). Indoor Residual Spraying. An operational manual for indoor residual spraying (IRS) for malaria transmission control and elimination. Second Edition, June 2015. World Health Organization (WHO), Geneva, Switzerland.

D is the insecticide application rate or target dosage of the insecticide to be used on the structures, based on the WHO recommendation (measured in grammes per square metre – g/m^2; C is the concentration of active ingredients in the insecticide formulation (i.e., % of active ingredients, a.i.) as recommended by the WHO; and H is the number of structures to be sprayed, estimated using the number of houses. Using the above quantification approach, we found that approximately 310,000 litres (310 million grammes) of insecticide (organophosphate: pirimiphos-methyl or Actellic) is required (including buffer stock) to spray only rooms for sleeping. However, the 310,000 litres could not be used to represent all sprayable surfaces in the country because it would be an underestimate as the UNHS data only captured rooms for sleeping. Given the data limitation, we conducted another computation based on IRS pilot data (i.e., data from the district-led approach of IRS implementation) from Northern Uganda to estimate the total volume of insecticides required to spray the entire house, not only rooms for sleeping. Evidence from the pilot data revealed that the Spray Rate (SR) for organophosphate (pirimiphos-methyl insecticide) is 3 houses per unit pack (tin of 1.5 litres or 1500 grammes)—i.e., every 1.5 litres covers between 2 to 5 houses, with an average of 3 houses (see appendix 1). Based on extrapolation of the pilot data, we estimate that to spray the entire country (covering approximately 8.5 million households or structures/houses), the required volume of insecticide (pirimiphos-methyl) would be 4.7 million litres (i.e., 4.7 billion grammes or 3.1 million packs/tins of 1.5 litres each), per spray round (including buffer stock). The pilot data revealed that the lifespan of a spray round for pirimiphos-methyl (Actellic) is close to one year (approximately 9 months), implying that a subsequent round of IRS can be performed after one year.

3.4 Types of insecticides included in the analysis

The IRS insecticides that were analysed are the chemicals that are recommended by WHO, as per the operational manual for IRS for malaria transmission control and elimination—second edition, June 2015 and those that have been piloted in Uganda under the National Malaria Control Programme or Presidential Malaria Initiate (PMI) IRS project. These are insecticides classified as carbamates and organophosphates[14]. The cost estimations were conducted using different options or types of carbamates and organophosphates. The carbamates were Bendiocarb (97% a.i. with a WHO recommended dosage of 0.1 g/m^2) and Propoxur (98% a.i. with a WHO recommended dosage of 1 g/m^2). However, we only reported the cost estimates for organophosphate (i.e., pirimiphos-methyl or Actellic) but not carbamates. This is because Actellic was successfully tested in the pilot districts of Northern Uganda. According to the WHO specification, pirimiphos-methyl contains 88% of a.i., and the recommended dosage is 1-2 g/m^2 (Table 2).

3.5 Data analysis

The analysis involved three key steps. The first was the determination of spray structures. The second was insecticide quantification through application of the WHO model (equation 1), although this could only be applied in the case of rooms used for sleeping and IRS pilot evidence from Northern Uganda (using an average S.R of 3 houses per unit pack of pirimiphos-methyl (Actellic) – this approach was used to analyse the overall quantity of insecticide required, as well as the cost of insecticide procurement. The last step was the application of unit cost analysis and extrapolation based on the IRS pilot evidence, as well as market price data. Detailed statistics on unit costs are presented in Appendix 1.

14 The use of pyrethroids has been phased out currently due to increased insecticide resistance.

Table 2: **Insecticide information**

Class/group (category of insecticide)	Insecticide type	Concentration (% of a.i.)	WHO recommended dosage (gm of a.i./ m^2	Action mode	Reason for inclusion in analysis
Carbamates (C)	Bendiocarb	97% (970 g/kg)	1	Contact & airborne	Recommended by the WHO for IRS
	Propoxur	98% (980 g/kg)	0.1 – 0.14	Contact & airborne	Recommended by the WHO for IRS
Organophosphate (OP)	Pirimiphos-methyl (Actellic)	88% (880 g/kg)	1 - 2	Contact & airborne	One of the insecticides recommended by the WHO It was tested/piloted and found to be effective in Northern Uganda

Source: Author's compilation based on WHO specification and pilot data from Northern Uganda

4.0 RESULTS AND DISCUSSION

4.1 Structures and spray operation

The results of the estimates of sprayable structures and computed spray rates are shown in Table 3. Overall, about 8.5 million structures exist for spraying. The sub-regions with the highest number of structures are: Central 1 (1,179,173), Central 2 (958,139), and Busoga (798,423). The estimated number of Spray Operators (SOPs) required to spray the 8.5 million structures countrywide was 41,719, an equivalence of 1.05 million person days. The distribution of SOPs was dependent on the existing structures per sub-region—the higher the number of structures, the more SOPs are required. If spray teams are to be created, 8,344 teams can be formed, assuming 5 SOPs per team. Based on the pilot evidence, 25 days are required for spraying at a spray rate of 8 structures per SOP per day. The estimated number of structures that each SOP can spray for the entire spray period is 203. Overall, approximately 338,000 structures were estimated to be sprayed each day by all the SOPs. If all structures are sprayed, it is expected that this will also cover approximately 8.5 million households.

Table 3: **Structures, spray operation and rates**

Sub-region	Sprayable structures	Structure each SOP can spray in 25 days	Spray teams	Total # SOPs	Total # days required for spraying, Spray Rate: 8 structures per SOP in a day		Districts
					Total structures that can be sprayed per day	Total days required for spraying	
Acholi	328,288	203	323	1,617	13,099	25	7
Ankole	714,311	203	704	3,519	28,502	25	10
Bugishu	424,486	203	418	2,091	16,938	25	8
Bukedi	415,768	203	410	2,048	16,590	25	6
Bunyoro	514,476	203	507	2,534	20,528	25	5
Busoga	798,423	203	787	3,933	31,858	25	10
Central1	1,179,173	203	1,162	5,809	47,051	25	12
Central2	958,139	203	944	4,720	38,231	25	11
Kampala	460,519	203	454	2,269	18,375	25	1
Karamoja	214,677	203	212	1,058	8,566	25	7
Kigezi	340,409	203	335	1,677	13,583	25	4
Lango	476,566	203	470	2,348	19,016	25	8
Teso	373,461	203	368	1,840	14,902	25	8
Tooro	592,827	203	584	2,920	23,655	25	7
West Nile	677,374	203	667	3,337	27,028	25	8
TOTAL	8,468,897	203	8,344	41,719	337,922	25	112

Source: Author's computation based on UNHS 2016/17, census data, and IRS pilot data.

In terms of spray team composition and supervision required to spray the 8.5 million structures, an estimated total of 41,719 Spray Operators (1.05 million person days), 14,490 Wash persons (0.36 million person days), 518 pump mechanics and 7,245 store keepers are required for countrywide implementation of IRS (Table 4 and Appendix 2). For supervision, 1,382, 1,680, and 672 supervisors are required at the sub-country, District Health Team (DHT), and district leadership levels, respectively. Other support team members required are 14,490 security guards and 560 drivers.

Table 4: **Estimates of spray teams and supervisors**

Sub-region	SOPs	Support – Loading / Off-loading	Pump mechanics	Supervisors DHT	Supervisors District leaders	Drivers
Acholi	1,617	10	20	105	42	35
Ankole	3,519	22	44	150	60	50
Bugishu	2,091	13	26	120	48	40
Bukedi	2,048	13	25	90	36	30
Bunyoro	2,534	16	31	75	30	25
Busoga	3,933	25	49	150	60	50
Central1	5,809	36	72	180	72	60
Central2	4,720	29	59	165	66	55
Kampala	2,269	14	28	15	6	5
Karamoja	1,058	7	13	105	42	35
Kigezi	1,677	10	21	60	24	20
Lango	2,348	15	29	120	48	40
Teso	1,840	11	23	120	48	40
Tooro	2,920	18	36	105	42	35
West Nile	3,337	21	41	120	48	40
TOTAL	41,719	260	517	1,680	672	560

Source: Author's computation based on UNHS 2016/17, Census data, and IRS pilot data.

4.2 Volume of insecticide required and associated costs

Table 5 shows the volume of insecticide [pirimiphos-methyl (Actellic)] required for the full coverage of households and structures in all the sub-regions of the country. The cost associated with the procurement of required insecticide for each sub-region is also presented. The results showed that a total of 3.1 million packs (equivalent to 4.7 million litres or 4.7 billion grammes) of pirimiphos-methyl (Actellic) is required (including buffer stock) to spray the 8.5 million structures to cover about 8.5 million households in the country. This is estimated at a spray coverage rate of 3 houses per pack of 1.5 litres of Actellic. It is expected that this volume of insecticide, if sprayed, will achieve a population coverage of approximately 39.8[15] million people. The population coverage ranges between 1.12 million people in the Karamoja sub-region and 5.07 million people in Central 1. The Central 1 sub-region requires the highest volume of insecticide, followed by Central 2 and Busoga, due to the large number of structures and households associated with them. The sub-regions with the least required insecticide volume are Karamoja, Acholi, and Kigezi, as they have the lowest sprayable structures.

Table 5: **Insecticide required by sub-region**

Sub-region	Structures	Spray Rate: structures sprayed @ pack	Total insecticide packs required – with buffer	Insecticide volume (Liters) – with buffer	Insecticide cost	Buffer stock cost (10%)	Total cost (UGX)
Acholi	328,288	3	120,372	180,558	5,471,466,667	547,146,667	6,018,613,333
Ankole	714,311	3	261,914	392,871	11,905,183,333	1,190,518,333	13,095,701,667
Bugishu	424,486	3	155,645	233,467	7,074,766,667	707,476,667	7,782,243,333
Bukedi	415,768	3	152,448	228,672	6,929,466,667	692,946,667	7,622,413,333
Bunyoro	514,476	3	188,641	282,962	8,574,600,000	857,460,000	9,432,060,000
Busoga	798,423	3	292,755	439,133	13,307,050,000	1,330,705,000	14,637,755,000
Central1	1,179,173	3	432,363	648,545	19,652,883,333	1,965,288,333	21,618,171,667
Central2	958,139	3	351,318	526,976	15,968,983,333	1,596,898,333	17,565,881,667
Kampala	460,519	3	168,857	253,285	7,675,316,667	767,531,667	8,442,848,333
Karamoja	214,677	3	78,715	118,072	3,577,950,000	357,795,000	3,935,745,000
Kigezi	340,409	3	124,817	187,225	5,673,483,333	567,348,333	6,240,831,667
Lango	476,566	3	174,741	262,111	7,942,766,667	794,276,667	8,737,043,333
Teso	373,461	3	136,936	205,404	6,224,350,000	622,435,000	6,846,785,000
Tooro	592,827	3	217,370	326,055	9,880,450,000	988,045,000	10,868,495,000
West Nile	677,374	3	248,370	372,556	11,289,566,667	1,128,956,667	12,418,523,333
National	8,468,897	3	3,105,262	4,657,893	141,148,283,333	14,114,828,333	155,263,111,667

Source: Author's computation from UNHS data (2016/17), IRS pilot data (2018)

4.3 Other spray logistics and facilities

In total, 41,719 spray pumps are required for each of the 41,719 SOPs (Table 6). Other key spray logistics that every SOP is required to have for IRS implementation include the following: protective gears such as respirators, overalls, boots, helmets, and gloves (see details in Table 6). Additionally, 7,245 soak pits are required to ensure environmental compliance, with an average of 483 pits per sub-region (i.e., one pit per parish). Additionally, to store the spray logistics in the communities, about 7,245 stores are required at the parish level (one per parish) (Appendix 2).

15 Considering 8,468,897 households countrywide, using an average national household size of 4.7

Table 6: **Estimates of required spray logistics**

	Overalls	Boots (pairs)	Helmets	Spray pumps	Gloves	Respirators	Buckets	Metallic buckets
Acholi	1,617	1,617	1,617	1,617	1,617	1,617	809	483
Ankole	3,519	3,519	3,519	3,519	3,519	3,519	1,759	483
Bugishu	2,091	2,091	2,091	2,091	2,091	2,091	1,046	483
Bukedi	2,048	2,048	2,048	2,048	2,048	2,048	1,024	483
Bunyoro	2,534	2,534	2,534	2,534	2,534	2,534	1,267	483
Busoga	3,933	3,933	3,933	3,933	3,933	3,933	1,967	483
Central1	5,809	5,809	5,809	5,809	5,809	5,809	2,904	483
Central2	4,720	4,720	4,720	4,720	4,720	4,720	2,360	483
Kampala	2,269	2,269	2,269	2,269	2,269	2,269	1,134	483
Karamoja	1,058	1,058	1,058	1,058	1,058	1,058	529	483
Kigezi	1,677	1,677	1,677	1,677	1,677	1,677	838	483
Lango	2,348	2,348	2,348	2,348	2,348	2,348	1,174	483
Teso	1,840	1,840	1,840	1,840	1,840	1,840	920	483
Tooro	2,920	2,920	2,920	2,920	2,920	2,920	1,460	483
West Nile	3,337	3,337	3,337	3,337	3,337	3,337	1,668	483
TOTAL	41,719	41,719	41,719	41,719	41,719	41,719	20,859	7,245

Source: Author's computation from UNHS data (2016/17), IRS pilot data (2018)

4.4 Cost estimates for universal IRS: National and sub-regional evidence

The overall cost estimate of the funds required to finance countrywide implementation of IRS is 235 billion shillings (Table 7), which is approximately 63.5 million US$. This is approximately 10% of the 2,308.4 billion shillings allocated from the national budget to the health sector in the current fiscal year (FY 2018/19). The cost components are as follows: human resources (21.4 billion); training (6.7 billion); Behavioural Change Communication (BCC; 417 million); spray logistics (42.3 billion); environmental compliance (254 million); transport logistics (589 million); storage at the community level (725 million); and insecticide procurement (155.3 billion) (Table 7). Overall, the cost per structure is 28,000 UGX (approximately 8 US$) at the national level on average (Table 9). The average cost per household and per person protected (or per capita cost) are 28,000 UGX (8 US$) and 6,000 UGX (2 US$), respectively (Table 9). The costs per structure and per person protected are less than half of the estimated costs incurred through the project-led approach (PMI project) in other countries such as Rwanda, Ethiopia, and Mali, among others. However, the per capita cost is comparable to Mauritius's approach whose IRS programme was very successful to the extent of eliminating malaria and was mainly driven by the government rather than by donor projects, although varying by IRS phase. The per capita cost during the prevention of re-introduction of malaria phases in Mauritius ranged between 2 and 3 USD, and 5-6 USD during elimination campaigns (WHO, 2012). The variations in costs were due to an emphasis on particular activities in different phases—for example, surveillance activities, including traveller's prophylaxis and passenger screening.

The share of insecticide procurement is 66% of the total cost compared with 34% for operational costs (Figure 4). This implies that the largest cost driver in an IRS programme is the procurement of insecticides. If spray logistics (e.g., spray pumps and respirators, among others) are excluded from the operational costs, assuming the utilization of existing spray logistics (discussed later in detail as a cost-minimization strategy), the share of operational costs is reduced to only 19%, but the insecticide procurement cost share substantially increases to 81% (Figure 5).

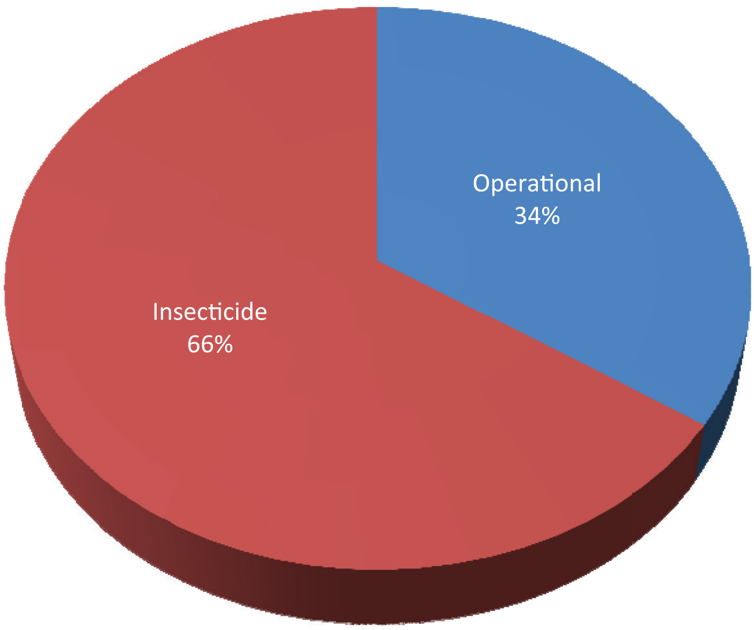
The largest components of the operational cost are spray logistics, IRS personnel (Human Resources) and training, estimated at 42.3, 21.4 and 6.7 billion shillings, respectively (Table 8). These represent 53%, 27%, and 8% of the operational costs, respectively. The Human Resource cost is majorly driven by costs of Spray Operators (SOPs) estimated to account for 54% of the personnel costs (11.5 billion), followed by the cost for wash persons at 5.4 billion shillings (Figure 6).

Table 7: **Cost summary by category**

Cost category/driver	Cost (UGX)	USD ($)
1. Implementation / Operational		
(a) IRS Human Resources & Supervision	21,429,256,576	
(b) Training	6,651,370,443	
(c) Behavioural Change Communication (BCC)	416,864,000	
(d) Spray logistics	42,322,510,182	
(e) Environmental compliance	253,575,000	
(f) Transport logistics	589,120,000	
(g) Storage – community level	724,500,000	
TOTAL – operational (misc. = 10%)	79,625,915,822	21,520,518
2. Insecticide procurement (buffer = 10%)	155,263,111,667	41,963,003
TOTAL (all)	234,889,027,489	63,483,521
TOTAL (without spray logistics)	192,566,517,307	52,045,005

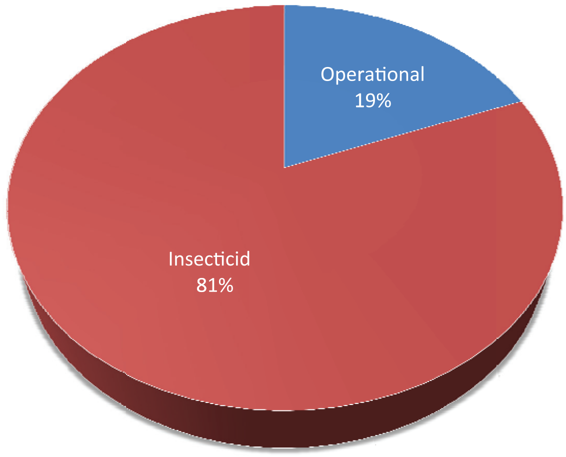
Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018

Figure 4: **Share of IRS costs, with operational costs including spray logistics**



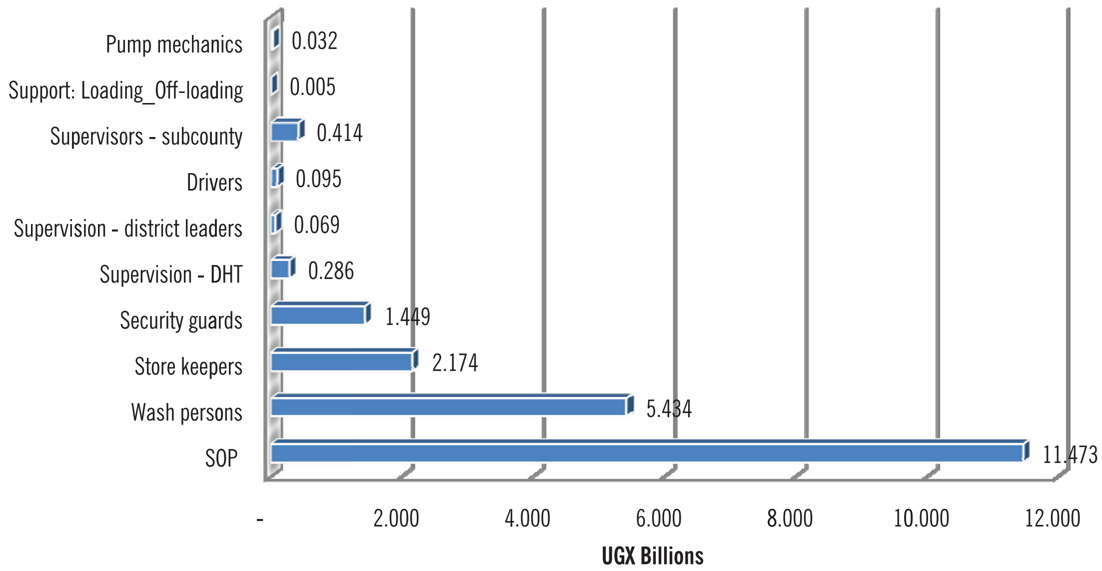
Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018

Figure 5: **Share of IRS costs, with operational costs excluding spray logistics**



Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018

Figure 6: **Disaggregated IRS human resource cost by HR component**



Source: Author's computation using UNHS 2016/17 data, IRS pilot data

Disaggregating the cost data by sub-region helps to plan a phased implementation of IRS in the country by understanding which resources are required for a given phase of implementation (e.g., using selected sub-regions with the highest malaria burden). Disaggregated cost results are presented in Table 8. The largest share of the cost is in Central 1 sub-region, estimated at 13% and 14% for operational and insecticide procurement costs, respectively. This is followed by Central 2 (share of 10% in operational costs and 11% in insecticide procurement costs) and Busoga (share of 9% in operational costs and 9% in insecticide procurement costs). The evidence on costs by sub-region showed that the distribution of costs follows the number of structures. Central 1 has the highest number of structures (1,179,173), and it is the sub-region associated with the highest share of the IRS implementation cost, followed by Central 2 (958,139 structures) and Busoga (798,423 structures). Other sub-regions with relatively higher numbers of structures and associated IRS implementation costs include Ankole, West Nile, and Tooro (see Tables 3 and 8 for the number of structures and associated costs, respectively).

To illustrate the cost implications of a phased implementation of IRS, we used evidence from the Uganda Malaria Indicator Survey (MIS) based on epidemiological stratification (UBOS & ICF International, 2010; UBOS & ICF International, 2015) and the Uganda Malaria Reduction Strategic Plan 2014-2020 (Republic of Uganda, 2014), which showed that the Mid-North (Acholi and Lango), East Central (Busoga), Central 2, and West Nile are the sub-regions with the highest burden of malaria out of the 15 sub-regions we have analysed, with prevalence rates of 63%, 56%, 51%, and 45%, respectively (Table 10). These are sub-regions associated with the highest prevalence of the malaria parasite (for example in children under 5 years). This implies that, if the government is to prioritize IRS implementation based on the malaria burden in the country, the cost implication requires mobilizing financial resources worth a total of 89.2 billion shillings (about 24 million US$) to implement the first phase of IRS, assuming the first phase targets the top four burdened sub-regions in the country (Table 10). Of the 89.2 billion shillings, 26% is estimated for the Mid-North (Acholi and Lango sub-regions, amounting to 22.9 billion shillings), 24% is for East central (amounting to 21.7 billion shillings), 29% is for Central 2 (worth 25.9 billion shillings), and 21% is for West Nile (worth 18.6 billion shillings) (Table 10).

We also used the latest Uganda Demographic and Health Survey (UDHS 2016) data to gauge high-burden sub-regions and provide financing requirement (cost) estimates to inform phased IRS implementation based on the current distribution of malaria burden. The UDHS data revealed that the first most burdened sub-regions (with malaria prevalence greater than 60% among children aged 6-59 months) are Karamoja (69%), Acholi (63%), and Lango (62%) [see Table 11 and UBOS & ICF (2018)]. The total amount of financing required considering these three sub-regions to form the first IRS phase is about 29.5 billion shillings (Table 11). The second most burdened sub-regions (prevalence of 50–60%) are Busoga (53%) and Teso (52%), which require financing of approximately 32.5 billion shillings. The third most burdened sub-regions (prevalence of 25-49%) comprise Bunyoro (32%), Bukedi (27%), and West Nile (25%). These require financing of about 44.7 billion shillings to implement IRS. Overall, the top three most burdened categories of sub-regions (with prevalence of at least 25%) require total funding of approximately 106.7 billion shillings (about 29 million US$) to roll out IRS in the eight top most burdened sub-regions of the country (Table 11). This is expected to cover a total of 3.8 million households and 19.2 million people at an average cost per structure and cost per person protected of 28,000 shillings (approximately 8 US$) and 6,000 shillings (close to 2 US$), respectively.

Alternatively, a phased implementation of IRS can be carried out such that the first phase covers the entire country (with approximately 8.5 million structures) or with at least 85% coverage as per WHO recommendations. With 85% IRS coverage rate, the required financing will be to the tune of about 199.66 billion shillings. Subsequent phases can be implemented sporadically, following the identification of malaria hotspots in different sub-regions and districts, as well as identification and spraying of dangerous water bodies.

One key lesson from Mauritius's successful IRS programme is that it is possible for the government to drive IRS as a major player, implement IRS through phased interventions, and eliminate malaria through domestic financing (see information box 2 for detailed lessons). However, it is important to note that, although lessons can be learnt, malaria prevention and the elimination success rate are highly dependent on the specific country context of IRS operation.

Information box 2: **Malaria prevention and elimination—lessons from Mauritius**

It is possible for governments to implement IRS to prevent and eliminate malaria through domestic financing. The malaria prevention and elimination programme in Mauritius was financed almost entirely using domestic resources. However, this is only possible with consistent domestic resource mobilization and funding backed with strong political will. For a successful programme, the financing landscape for IRS malaria intervention must change. It requires considering malaria prevention and elimination (through IRS) as a recurring investment, similar to interventions such as routine vaccination or child immunization. Mauritius did this with a per capita investment of over 2 USD per annum. Additionally, opportunities for expenditure minimization must be identified to ensure cost-effectiveness as well as counteract resource constraints during an economic downturn and declining external funding.

In terms of political will, leaders must be committed to the cause of preventing and eliminating malaria. Additionally, government technocrats and other stakeholders must demonstrate concerted and persistent efforts to this cause. As was achieved in Mauritius, to be successful, government and all stakeholders must have a united front against malaria, and organize a military-like offensive to attack it, with a common goal of eliminating it.

Regarding external financing for IRS, the evidence from Mauritius shows that donors make some important contribution in IRS implementation. For example, although limited, WHO provided some financial and other resources such as transport equipment (e.g., vehicles and motorcycles for surveillance), insecticides, environmental projects, technical support and training). However, external funding alone may not deliver results for malaria elimination. This is because of uncertainties associated with donor funding, and probable mismatch between donor and national interest.

Another important lesson to learn is that countries face the risk of malaria resurgence until malaria eradication is achieved. One of the highest risk factors to bear in mind is malaria importation. This must be well-understood and addressed through passenger screening initiatives and routine malaria surveillance.

SOURCE: Author’s compilation using WHO (2012)

Table 8: **Detailed cost estimates by sub-region (UGX)**

Sub-region	BCC cost	Environmental compliance	HR cost	Transport logistic cost	Training cost	Spray logistics cost	Storage cost	Total operational cost	Insecticide cost
Acholi	26,054,000	16,905,000	1,105,594,121	36,820,000	326,318,227	1,644,631,271	48,300,000	3,525,084,880	6,018,613,333
Ankole	37,220,000	16,905,000	1,642,255,048	52,600,000	520,977,340	3,567,139,906	48,300,000	6,473,937,024	13,095,701,667
Bugishu	29,776,000	16,905,000	1,240,344,105	42,080,000	375,206,404	2,123,725,744	48,300,000	4,263,970,978	7,782,243,333
Bukedi	22,332,000	16,905,000	1,220,471,898	31,560,000	367,911,823	2,080,307,527	48,300,000	4,166,567,073	7,622,413,333
Bunyoro	18,610,000	16,905,000	1,350,609,100	26,300,000	415,036,453	2,571,902,542	48,300,000	4,892,429,405	9,432,060,000
Busoga	37,220,000	16,905,000	1,756,567,543	52,600,000	562,411,823	3,986,042,527	48,300,000	7,106,051,582	14,637,755,000
Central1	44,664,000	16,905,000	2,282,050,195	63,120,000	752,973,399	5,882,290,064	48,300,000	9,999,332,923	21,618,171,667
Central2	40,942,000	16,905,000	1,977,641,725	57,860,000	642,589,655	4,781,475,414	48,300,000	8,322,285,174	17,565,881,667
Kampala	3,722,000	16,905,000	1,261,230,788	5,260,000	382,456,650	2,303,180,734	48,300,000	4,423,160,689	8,442,848,333
Karamoja	26,054,000	16,905,000	951,190,982	36,820,000	270,352,217	1,078,814,911	48,300,000	2,671,280,822	3,935,745,000
Kigezi	14,888,000	16,905,000	1,110,031,177	21,040,000	327,789,163	1,704,997,433	48,300,000	3,568,345,851	6,240,831,667
Lango	29,776,000	16,905,000	1,311,123,479	42,080,000	400,861,576	2,383,099,537	48,300,000	4,655,360,151	8,737,043,333
Teso	29,776,000	16,905,000	1,170,998,530	42,080,000	350,070,936	1,869,606,163	48,300,000	3,880,510,291	6,846,785,000
Tooro	26,054,000	16,905,000	1,465,116,102	36,820,000	456,633,005	2,962,113,680	48,300,000	5,513,135,965	10,868,495,000
West Nile	29,776,000	16,905,000	1,584,031,783	42,080,000	499,781,773	3,383,182,729	48,300,000	6,164,463,014	12,418,523,333
TOTAL	416,864,000	253,575,000	21,429,256,576	589,120,000	6,651,370,443	42,322,510,182	724,500,000	79,625,915,822	155,263,111,667

Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018

Table 9: **Coverage, cost per structure and per capita cost of IRS**

Sub-region	Structure	Total operational cost	Insecticide cost	Total cost - All	Household (HH) size	Population	Cost per structure	Per capita cost
Acholi	328,288	3,525,084,880	6,018,613,333	9,543,698,213	5.5	1,805,584	29,071	5,286
Ankole	714,311	6,473,937,024	13,095,701,667	19,569,638,691	4.7	3,357,262	27,397	5,829
Bugishu	424,486	4,263,970,978	7,782,243,333	12,046,214,311	4.8	2,037,533	28,378	5,912
Bukedi	415,768	4,166,567,073	7,622,413,333	11,788,980,406	5.3	2,203,570	28,355	5,350
Bunyoro	514,476	4,892,429,405	9,432,060,000	14,324,489,405	4.7	2,418,037	27,843	5,924
Busoga	798,423	7,106,051,582	14,637,755,000	21,743,806,582	4.9	3,912,273	27,233	5,558
Central1	1,179,173	9,999,332,923	21,618,171,667	31,617,504,590	4.3	5,070,444	26,813	6,236
Central2	958,139	8,322,285,174	17,565,881,667	25,888,166,840	4.5	4,311,626	27,019	6,004
Kampala	460,519	4,423,160,689	8,442,848,333	12,866,009,023	3.7	1,703,920	27,938	7,551
Karamoja	214,677	2,671,280,822	3,935,745,000	6,607,025,822	5.2	1,116,320	30,777	5,919
Kigezi	340,409	3,568,345,851	6,240,831,667	9,809,177,517	4.5	1,531,841	28,816	6,404
Lango	476,566	4,655,360,151	8,737,043,333	13,392,403,484	5.1	2,430,487	28,102	5,510
Teso	373,461	3,880,510,291	6,846,785,000	10,727,295,291	6.1	2,278,112	28,724	4,709
Tooro	592,827	5,513,135,965	10,868,495,000	16,381,630,965	4.8	2,845,570	27,633	5,757
West Nile	677,374	6,164,463,014	12,418,523,333	18,582,986,348	4.5	3,048,183	27,434	6,096
UGANDA	8,468,897	79,625,915,822	155,263,111,667	234,889,027,488	4.7	39,803,816	27,735	5,901

Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018.

Table 10: **IRS costs in high burden sub-regions based on MIS data**

Sub-region	Prevalence, %	Operational Cost	Insecticide Cost	Total Cost - All	Structures	HH size	Population	Cost per structure	Cost per person	% total cost
Mid-North	63	8,180,445,031	14,755,656,667	22,936,101,698	804,854	5.3	4,265,726	28,497	5,377	25.73
Busoga	56	7,106,051,582	14,637,755,000	21,743,806,582	798,423	4.9	3,912,273	27,233	5,558	24.39
Central2	51	8,322,285,174	17,565,881,667	25,888,166,840	958,139	4.5	4,311,626	27,019	6,004	29.04
West Nile	45	6,164,463,014	12,418,523,333	18,582,986,348	677,374	4.5	3,048,183	27,434	6,096	20.84
TOTAL - High Burden Sub-regions 1	54	29,773,244,801	59,377,816,667	89,151,061,467	3,238,790	4.8	15,537,807	27,526	5,738	100.00

Source: Author's computation using UNHS 2016/17 data, IRS pilot data, MIS data, and market price data 2018.

Table 11: **IRS costs in high burden sub-regions based on UDHS data**

Sub-region	**Prevalence, %**	**Operational**	**Insecticide**	**Total cost - All**	**Structures**	**HH size**	**Population**	**Cost per structure**	**Cost per person**	**% total cost**
Acholi	63	3,525,084,880	6,018,613,333	9,543,698,213	328,288	5.5	1,805,584	29,071	5,286	8.94
Bukedi	27	4,166,567,073	7,622,413,333	11,788,980,406	415,768	5.3	2,203,570	28,355	5,350	11.05
Bunyoro	32	4,892,429,405	9,432,060,000	14,324,489,405	514,476	4.7	2,418,037	27,843	5,924	13.42
Busoga	53	7,106,051,582	14,637,755,000	21,743,806,582	798,423	4.9	3,912,273	27,233	5,558	20.38
Karamoja	69	2,671,280,822	3,935,745,000	6,607,025,822	214,677	5.2	1,116,320	30,777	5,919	6.19
Lango	62	4,655,360,151	8,737,043,333	13,392,403,484	476,566	5.1	2,430,487	28,102	5,510	12.55
Teso	52	3,880,510,291	6,846,785,000	10,727,295,291	373,461	6.1	2,278,112	28,724	4,709	10.05
West Nile	25	6,164,463,014	12,418,523,333	18,582,986,348	677,374	4.5	3,048,183	27,434	6,096	17.41
TOTAL	48	37,061,747,217	69,648,938,333	106,710,685,551	3,799,033	5.2	19,212,566	28,442	5,554	100.00

Source: Author's computation using UNHS 2016/17 data, IRS pilot data, UDHS data, and market price data 2018.

4.5 Comparison of costs—different malaria prevention and treatment strategies

This section discusses a comparison of IRS implementation costs using the integrated district-led approach and project approach of implementation. We also compared the estimated IRS costs based on the two approaches of IRS implementation with the cost of malaria treatment, and prevention using LLINs.

The results showed that implementing IRS using the project-led approach is costlier than using a district-led approach by almost six-fold. Therefore, the district-led approach, which costs approximately 235 billion shillings, is cheaper than the project-led approach (estimated at 1,300 billion shillings;- Table 12). Additionally, utilization of existing local government structures (district-led strategy) is instrumental as a cost-cutting measure for IRS implementation as opposed to a project-led strategy. The use of LLINs as a malaria-prevention strategy costs about 370 billion shillings per universal coverage round, higher than the cost of implementing one round of IRS by approximately 135 billion shillings. However, if LLINs are assumed to last for 2.5 years, the estimated annual cost of implementing LLINs is 148 billion shillings, which is comparable to the IRS implementation cost of 235 and 186 billion shillings with and without spray logistics, respectively (Table 12). Importantly, IRS is associated with higher effectiveness than ITNs because of several reasons. First, ITNs have a narrower scope of protection (i.e., only in beds) than IRS. Second, most structures in rural areas do not support the use of ITNs, forcing households to use ITNs for other purposes rather than malaria protection[16]. Finally, in general, ITN usage is not guaranteed. Most importantly, a combination of both approaches (IRS and ITNs) can boost the effectiveness of the fight against malaria. However, if one was to be prioritized, IRS would be a better choice based on the available evidence.

The cost of implementing IRS is also relatively cheaper than malaria case management (treatment). The evidence in Table 12 shows that the annual cost of case management is about 588 billion shillings, which more than doubles the cost of implementing IRS using the district-led approach (based on organophosphate pirimiphos-methyl insecticide, whose lifespan is approximately one year after spraying). This includes both direct and indirect costs related to the treatment of malaria, quantified

16 This was reported by a Key Informant in the District Health Office—experience from the Agago district.

Table 12: **Estimated costs under different malaria prevention and treatment options**

Strategy	Cost (UGX)	Cost (UGX – Billions)
District Led Approach of IRS (with spray logistics)	234,889,027,489	235
District Led Approach of IRS (without spray logistics)	192,566,517,307	193
Project Approach of IRS	1,258,000,000,000	1,300
Annual cost of case management (treatment)[1] – direct & indirect		
(a) Direct cost	120,798,340,000	121
(b) Indirect cost	467,489,575,800	468
Total costs related to case management	588,287,915,800	588
LLIN (mosquito nets) cost per universal coverage round	370,000,000,000	370
LLIN annual cost – assuming LLINs last 2.5 years	148,000,000,000	148

Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018, and MoH malaria statistics (various years). NOTE: IRS cost computation is based on actellic (insecticide) which can be implemented approximately one round per year.

in monetary terms. The quantification captures the opportunity cost of the time spent by households seeking treatment, the period of complete incapacitation and recuperation, and the productive time lost by patients and care givers (see also Okorosobo et al., 2011). The evidence is a clear demonstration that putting emphasis on or increased investments in malaria-prevention measures (e.g., IRS) is less costly to the country, presenting an opportunity to save costs in the fight against malaria.

4.6 IRS cost-reduction strategies and related costs

The Ugandan economy, similar to many other poor economies in developing countries, operates in a highly resource-constrained environment, coupled with numerous competing development priorities and needs. As such, exploring low-cost options for healthcare intervention (such as IRS) implementation is necessary. Based on pilot evidence from the Northern region, several IRS cost-reduction strategies can be employed to minimize the cost of implementing IRS in the country (see the summary of cost-reduction scenarios and related costs in Table 13). This can be done through utilization of existing District Local Government and community-based structures, as well as spray logistics (e.g., pumps) that are in place (e.g., in the IRS pilot districts). If such structures and logistics are effectively utilized, some of the operational cost items (e.g., spray logistics and SOPs) can be eliminated from the cost of operation for IRS implementation, hence lowering the financial resources needed.

A cost-reduction strategy such as the exclusion of spray logistics (e.g., spray pumps) can work if government decides to use existing spray logistics on a rotational basis, moving the logistics from one district to another, as implemented in the North. Another strategy employed in the North is the utilization of district stores and community stores to store spray logistics. Regarding community stores, community members who have storage space or facilities are identified and recruited as security guards on the condition that they offer their stores for keeping spray logistics. Alternatively, existing health facilities (hospitals, HCIVs, HCIIIs and HCIIs) can be utilized to provide storage facilities. The use of health facilities can also potentially eliminate the personnel cost on security guards because health facilities already have security guards (*Askaris*). Further cost-reduction strategies involve options such as the use of Village Health Teams (VHTs) or the Ministry of Health's proposed Community Health Extension Workers (CHEWs) as SOPs, ensuring that IRS implementation (particularly spraying) is incorporated into their routine activities within the communities. This can eliminate or greatly minimize the cost of paying SOPs. Additionally, the idea of using wash-persons was conceived in a project-led approach of IRS implementation (e.g., under the PMI), and key informant information from the North revealed that the work of wash-persons can be done by the SOPs after spraying every day, hence eliminating expenditure on wash persons. Finally, based on KI information from the pilot districts, BCC for IRS can be incorporated within the national immunization day BCC. The immunization BCC is an annual sensitization campaign for immunization, and messages for sensitizing communities about IRS can easily be incorporated in it. If this is done, the cost of IRS BCC can be eliminated as an operational cost item.

Therefore, cost-reduction options under operational costs include cost scenarios 2, 3, 4, 5, and 6 (see Table 13). Scenario 2 occurs when the operational costs are considered excluding spray pumps as a cost-reduction strategy. The exclusion of spray pumps as a cost item implies that districts use existing spray pumps (e.g., spray pumps in the Northern and Eastern regions) on a rotational basis. Using this scenario, operational costs can be cut by 42% (from 79,625,915,822 to

46,250,952,275 shillings). Scenario 3 occurs when all spray logistics are excluded from the operational costs, assuming that districts utilize existing spray logistics on a rotational basis. This strategy can cut the operational costs of IRS by more than half, from 79.6 to 37.3 billion shillings. Scenario 4 occurs when spray logistics and storage are excluded as operational cost items, with storage assumed to be catered for by community-based stores or the use of existing health facility stores. This reduces operational costs by approximately 54%, from 79.6 to 36.6 billion shillings. When scenario 5 is considered as a cost-reduction strategy (i.e., exclusion of spray logistics, storage and SOPs), the IRS operational costs can be reduced by 68%, from 79.6 to 25 billion shillings. However, if this strategy is used when SOPs (e.g., VHTs or CHEWs) are facilitated with a daily allowance that is half of the wage of a full-time SOP (about 5,500 shillings per day worked), the strategy can reduce costs by approximately 61% (from 79.6 to 31 billion shillings). The last cost-reduction strategy is the exclusion of spray logistics, storage, SOPs, BCC and wash-persons. This is expected to cut IRS operational costs by 76%, from 79.6 to 19.3 billion shillings.

If the utilization of spray logistics on a rotational basis is considered unfeasible for IRS implementation in the entire country, perhaps due to reasons such as the difficulty in logistics/ equipment transfer and wear and tear, among others, the cost-reduction option of excluding SOPs, storage and security guards can be considered. If this is done, the operational cost can be reduced by 17%, from 79.6 to 66 billion shillings (see the column for cost7, Table 13).

Other options that can be employed to reduce the cost of IRS implementation include the use of locally available human resources such as the forces[17] and jobless youth. Rather than making use of VHTs or CHEWs as SOPs, government can explore the use of the forces (i.e., military personnel or police) to carry out spray activities (especially the actual spraying of houses). Redundant personnel in the military or police can be identified and deployed during the time of IRS implementation. These can be facilitated at lower rates—for example, half of the full-time SOP's wage. Another alternative that can be explored is the available jobless youth in the country. According to UBOS (2016), 14% of Ugandan youth are idle (neither in employment nor in education), representing about 1.2 million youth. If such human resources from the youth could be harnessed, this would go a long way in cutting IRS implementation costs, as well as curbing the problem of youth unemployment in the country.

Concerning insecticide costs, medium- to long-term solutions can be devised. Given that insecticide costs consume the largest portion of IRS financing requirements, it is also important to explore ways to minimize the costs of acquiring IRS insecticides. There are two options that the government can choose for the local manufacturing of insecticides. The first is that the government can set up a local industry to manufacture insecticides. The second option is, instead of establishing a new industry, the government can support local initiatives such as Cipla Quality Chemical Industries or the Tororo-based chemical factory to manufacture insecticides for IRS domestically.

In the medium to long term, government support towards the local manufacture of chemicals/insecticides, can take the form of subsidies or related manufacturing incentives. The support for local chemical production can be geared towards the manufacture of organophosphate (e.g., Actellic). However, for this to work, procedures related to chemical manufacture licensing and/or patents, as well as standards, should be streamlined with the relevant local and international bodies. For example, in collaboration with the WHO, it is

17 Uganda Peoples Defense Force (UPDF) and Uganda Police.

important to deal with patentability to allow the production of generic brands of insecticides, given the exorbitant cost of innovator brands.

Domestic production can be undertaken through a Public-Private-Partnership (PPP) arrangement or creating an enabling environment for the private sector to take the lead in insecticide manufacturing. However, for any domestic manufacturing initiative to be successful, there must be robust transparency and accountability mechanisms to ensure that all processes involved are not abused.

We envisage local insecticide production as a viable and sustainable venture that can be undertaken, with a strong business case, particularly because of large market potentials for insecticide. The first market is, available within at least 8.5 million households in the country that can be sprayed. The second market potential is considering the East African Community regional market, where Cipla Quality Chemical Industries has already gained ground in terms of the production and supply of Anti-Retroviral (ARV) and ACT (antimalarial) medications. Locally produced insecticides can be marketed within the East African region and beyond, given the promising market potential. For example, by 2017/18, Cipla Quality Chemical Industries had expanded its geographical presence in terms of sales to 9 African countries, covering East, West and South African countries. The third is considering the agricultural sector. Because insecticides such as Actellic originate from the same group of insecticides used for spraying crops against pests, the local manufacturer can diversify their line of insecticide production from IRS insecticides to chemicals used in spraying crops. It is also worth noting that local insecticide production offers additional benefits to the economy in terms of employment, investments, and possibilities of boosting the trade balance.

Other identified cost-reduction strategies include the use of customized spray pumps, deployment of non-technical supervision structures only during the first IRS round, insecticide sourcing at competitive rates, domestic financing for IRS, and private sector model of service delivery mixed with a public health approach.

On customized spray pumps, the sprayers can be modified to suit local conditions—for example, through modification of pumps used for spraying crops—to ensure they are suitable for IRS. For supervision, political and high administrative unit supervision structures (such as; District Chairpersons - LCVs, Resident District Commissioners - RDCs, and Chief Administrative Officers - CAOs) are engaged to conduct sensitization and supervision only in the first round of IRS. Due to the need to minimize the cost of operation, these structures can be dropped in subsequent rounds of spraying (i.e., after rallying political will in the first round). The supervision structures that can be maintained in subsequent spray rounds are District Health Teams (DHTs) and field/spray supervisors.

Regarding insecticide sourcing, deliberate moves to contain the high cost of insecticide can be made by ensuring that the chemicals are sourced from relatively cheaper suppliers. It was discovered during market survey (as well as interviews with key stakeholders) that the current sources of insecticides are too expensive. However, there are available options that can cost 2-3 times less. Given the financing status-quo, IRS programmes are primarily donor funded, and there is no room for flexibility in sourcing insecticides. Almost all programmes must procure insecticides from "ring-fenced" costly sources. Therefore, it is important that insecticides are obtained from relatively cheaper sources to abate the high cost of procurement. Domestic IRS financing is key to enable the flexibility in sourcing. Through domestic financing, the government can influence the procurement of insecticides from non-inflated sources. It is also critical for the government (Ministry of Health) to have the power to determine the IRS implementation approach, including who to deploy and the deployment of local resources. Accordingly, it is prudent for the government to increase IRS funding from the current 2 billion shillings[18] per annum to scale up IRS and control the choice of insecticide sources, as well as determine who (or what) to deploy.

The last strategy is promoting the private sector model of service delivery for IRS but with a strong regulatory framework[19], mixed with a public health approach. This involves a shift in the approach to IRS service delivery to a private sector-driven model, especially targeting the middle class or elites who can directly purchase IRS services, given their relatively high ability to afford. Here, government SOPs can be established (with guidance from MoH) and can be contracted by private individuals to spray their houses—the money paid can be channelled to government coffers to support IRS. Potential markets include private individuals, hotels, schools, and plantations, among others. The private-sector approach will help to transfer some of the costs of IRS to households and other actors. This strategy can be combined with the application of a public health approach targeting the poor or rural households. The public health strategy involves the government implementing IRS for free, for the poor or rural population.

18 Key Informant Information from Ministry of Health – Uganda (2019).

19 Regulation for private players (fumigators, sprayers, or pest control agents), and chemical dealers.

Table 13: **IRS costs under different cost reduction strategies/scenarios (costs in UGX)**

Sub-region	Cost 1	Cost 2	Cost 3	Cost 4	Cost 5	Cost 6	Cost 7	Insecticide total cost
Acholi	3,525,084,880	2,231,339,067	1,880,453,609	1,832,153,609	1,387,428,486	999,124,486	2,935,459,757	6,018,613,333
Ankole	6,473,937,024	3,658,918,305	2,906,797,118	2,858,497,118	1,890,834,433	1,491,364,433	5,361,374,339	13,095,701,667
Bugishu	4,263,970,978	2,591,119,746	2,140,245,234	2,091,945,234	1,516,902,623	1,124,876,623	3,544,028,367	7,782,243,333
Bukedi	4,166,567,073	2,528,072,492	2,086,259,546	2,037,959,546	1,474,727,034	1,090,145,034	3,458,434,561	7,622,413,333
Bunyoro	4,892,429,405	2,864,937,779	2,320,526,863	2,272,226,863	1,575,276,617	1,194,416,617	4,050,579,159	9,432,060,000
Busoga	7,106,051,582	3,959,557,000	3,120,009,054	3,071,709,054	1,990,101,542	1,590,631,542	5,879,544,069	14,637,755,000
Central1	9,999,332,923	5,352,345,731	4,117,042,859	4,068,742,859	2,471,341,012	2,064,427,012	8,257,031,076	21,618,171,667
Central2	8,322,285,174	4,546,367,932	3,540,809,760	3,492,509,760	2,194,538,208	1,791,346,208	6,879,413,622	17,565,881,667
Kampala	4,423,160,689	2,608,307,487	2,119,979,955	2,071,679,955	1,447,824,167	1,081,852,167	3,654,404,901	8,442,848,333
Karamoja	2,671,280,822	1,825,263,088	1,592,465,910	1,544,165,910	1,253,347,314	865,043,314	2,235,562,225	3,935,745,000
Kigezi	3,568,345,851	2,226,832,550	1,863,348,417	1,815,048,417	1,353,903,220	976,765,220	2,962,300,654	6,240,831,667
Lango	4,655,360,151	2,777,267,540	2,272,260,614	2,223,960,614	1,578,366,279	1,186,340,279	3,864,865,816	8,737,043,333
Teso	3,880,510,291	2,408,742,803	2,010,904,128	1,962,604,128	1,456,684,054	1,064,658,054	3,229,690,217	6,846,785,000
Tooro	5,513,135,965	3,176,871,926	2,551,022,286	2,502,722,286	1,699,631,522	1,311,327,522	4,565,145,202	10,868,495,000
West Nile	6,164,463,014	3,495,008,827	2,781,280,285	2,732,980,285	1,815,355,408	1,423,329,408	5,101,938,137	12,418,523,333
TOTAL	79,625,915,822	46,250,952,275	37,303,405,639	36,578,905,639	25,106,261,920	19,255,647,920	65,979,772,102	155,263,111,667

Source: Author's computation using UNHS 2016/17 data, IRS pilot data, and market price data 2018. Operational cost categories: 1= All operational costs; 2, 3, 4, 5, 6 and 7 represent operational costs excluding spray pumps; all spray logistics; spray logistics & storage; spray logistics, storage & SOPs; spray logistics, storage, SOPs, Wash-persons & BCC; and SOPs, storage, and security guards.

5.0 CONCLUSION AND POLICY RECOMMENDATIONS

Uganda contributes disproportionately to the malaria burden in Africa; it is the second largest contributor of the total estimated malaria cases in East and Southern Africa. Domestically, malaria remains the leading cause of mortality and morbidity. The most affected population segments are children younger than five years and pregnant women. However, malaria is endemic in approximately 95% of the country; hence, it also affects the rest of the population, imposing a gross economic burden due to related healthcare costs, loss of workdays and decreased productivity. In response to the persistent malaria burden, the Ministry of Health proposes IRS-preventive measures among other interventions. Indeed, there is renewed interest in the current malaria-reduction strategic plan for large-scale IRS programme implementation as a major component of current malaria control efforts. Additionally, recently, the political leadership (His Excellency, the President of Uganda) voiced solidarity towards fighting malaria through IRS by launching the "*Kick Malaria out of Uganda*" campaign. However, there are important considerations to make as the country prepares to scale up IRS; requisite financial resources must be planned to fund country-wide implementation. Additionally, Uganda, similar to other poor economies, operates in a highly resource-constrained environment, in addition to innumerable competing development priorities and needs, making exploring low-cost IRS strategies imperative.

This paper estimated costs for a country-wide roll out of IRS using a district-led approach of implementation, examined the cost implications of implementing IRS in a phased manner, and identified cost-minimization strategies for IRS. The paper also examined costs under different IRS delivery channels—the project-based delivery versus the integrated district-led model—and highlights the affordability and financial sustainability of IRS to the government.

Overall, there is an estimated 8.5 million structures for spraying. Sub-regions with the largest number of structures are Central 1, Central 2, and Busoga. To spray all structures, almost 42,000 Spray Operators (SOPs) are required (equivalent to 1.05 million person days); the distribution of SOPs across sub-regions and districts is dependent on the number of structures. Approximately 3.1 million packs (of 1.5 litres), an equivalence of 4.7 billion grammes of pirimiphos-methyl (Actellic), is required to spray all the structures. Evidence has shown that 25 days are required for spraying, at a spray rate of 8 structures per SOP per day. If all the structures are sprayed, it is expected that this will cover at least 8.5 million and 40 million households and people, respectively.

The results showed that, to finance country-wide implementation of IRS using a district-led approach, 235 billion shillings (about 63.5 million US$) is required, which is approximately 10% of the national budget allocated to the health sector in the current fiscal year. The overall cost per structure is 28,000 shillings (8 US$), and, the cost per household and per person protected, are 28,000 UGX and 6,000 UGX (2 US$), respectively. Sub-regions with more structures (e.g., Central 1, Central 2, and Busoga) require more financial resources to fund IRS implementation.

The largest cost driver of an IRS programme is the procurement of insecticides, which accounts for approximately 66% of the total cost. The exclusion of spray logistics from operational costs (if existing logistics are utilized) reduces the share of operational costs to only 19%, making the insecticide procurement cost share to substantially rise to 81%. Therefore, spray logistics are the largest component of operational costs (representing

53% of operational costs), followed by IRS personnel (27%), and training (8%). Personnel cost is primarily driven by costs on SOPs, estimated at 54%.

If IRS implementation is carried out in a phased manner based on the most burdened sub-regions, the following three sets of sub-regions can be prioritized. The first set is Karamoja, Acholi, and Lango, which are sub-regions with the highest burden; if they are considered to form phase 1, 29.5 billion shillings is required to finance IRS. The second set of sub-regions comprises Busoga and Teso. If these are considered as the second phase, it requires financing of about 32.5 billion shillings. The final set of sub-regions to be prioritized is Bunyoro, Bukedi, and West Nile. These require financing to the level of 44.7 billion shillings. Overall, the top three most burdened sets of sub-regions require a total financing of 106.7 billion shillings (about 29 million US$) to roll out IRS in the eight top most burdened sub-regions of the country. Lessons drawn from Mauritius demonstrated that it is possible for the government to implement IRS as a major player, and implementation can be phased, through domestic financing to eliminate malaria. Elimination can be achieved with consistent domestic resource mobilization and funding supported by strong political will for IRS. Therefore, the financing landscape must change, targeting malaria prevention and elimination as a recurring investment, similar to routine vaccination.

It is vital to recognize that all districts may wish to prioritize IRS. The limitation here is that shared equipment (in circumstances of the use of equipment rotationally, or when phasing) may not be adequate to cover the country at the same time. However, regionally shared equipment can help to address the issue of expediting coverage (for example, before the rainy season).

Further evidence has shown that the integrated district model of IRS implementation is associated with the least cost compared with other strategies. Implementing IRS using the project-led approach costs almost six-fold (1,300 billion shillings) more than the costs for the district-led approach (235 billion shillings). The evidence suggestes that utilization of existing local government structures (based on the district-led strategy) is instrumental as a cost-cutting measure for IRS implementation. The results also demonstrated that the estimated annual cost of implementing LLINs is comparable to the IRS implementation cost. However, IRS is optimal based on effectiveness criterion. This is because with IRS, people have a wider scope of protection against malaria (beyond their bedrooms), but LLINs cannot protect people outside their beds; yet, there is no guarantee for net usage. Most structures (especially in rural areas) also do not support the use of nets; hence, many households tend not to use the nets for the intended purpose. Compared with case management, IRS is still the cheaper option—the annual cost of case management is approximately 588 billion shillings, which more than doubles the cost of implementing IRS using the district-led approach.

Accordingly, our findings suggest that more emphasis or investments in malaria prevention using IRS is a less costly venture for government to take up and presents an opportunity to save costs in the fight against malaria; hence, a seemingly more sustainable measure. The evidence also indicates that the government should utilize existing District Local Government and community-based structures, as well as spray logistics that are in place in IRS pilot districts as a basis to minimize the cost of IRS implementation. Some of the specific IRS low-cost strategies for consideration include:

- Use of existing spray logistics on a rotational basis, as implemented in IRS pilot districts, considering some regional sets of equipment for easy planning and coverage efficiency.

- Utilization of district resources or assets instead of duplications—for example, district and community stores to store spray logistics. Alternatively, existing health facilities can be utilized to provide storage facilities. The use of health facilities can also potentially eliminate some elements of personnel cost.
- Further cost-reduction strategies involve options such as the use of Village Health Teams (VHTs) or Ministry of Health's proposed Community Health Extension Workers (CHEWs) as SOPs, ensuring that IRS implementation is incorporated into their routine activities within the communities, and making them perform the role of wash-persons as well. Other options that can be employed include the use of locally available human resources such as the uniformed forces and youth. The government can explore the use of the forces (i.e., military personnel or police) to carry out spray activities as a "national service" assignment. There are approximately 1.2 million idle youth. If harnessed, this group can provide a low-cost venture and contribute to addressing the youth unemployment problem with which the country grapples.
- Behavioural Change Communication (BCC) for IRS can be incorporated within the national immunization day BCC. Messages to sensitize communities about IRS can be incorporated into the immunization BCC annual sensitization campaign.
- Regarding insecticide costs, the government can opt, in the medium to long term, to provide support towards the local manufacture of IRS chemicals, through subsidies or the provision of fiscal incentives to manufacture the insecticides. The support should be directed towards a local chemical firm(s).
- Other options include insecticide sourcing at competitive rates, domestic IRS financing, and private sector model of service delivery combined with a public health approach.

Finally, as evident, insecticides and other spray equipment are the largest cost drivers of an IRS programme. As a policy option, the government and development partners can undertake cost-sharing strategies. Here, donors with a stake in malaria prevention can support the procurement of insecticides and spray equipment, while the government finances IRS operations.

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APPENDIX

Appendix 1: Unit cost statistics

Key cost items	Unit cost (UGX)
Human Resources and Supervision	
SOPs – wage rate	11,000 UGX per day worked
Wash persons – wage rate	15,000 per day worked
Store keepers	12,000 per day worked
Security guards	100,000 per guard - entire spray period
Pump mechanics	500,000 – entire spray period
Supervision - DHT	17,000 per DHT member per day of supervision
Supervision – District leaders (CAO, LCV, RDC, etc.)	17,000 per district leader per day of supervision
Supervisors – Sub-county level	12,000 per day worked
Drivers for supervision (DHT & district leaders)	17,000 per day worked
Support staff (loading/off-loading)	72,000
Chemical (insecticide)	
Pirimiphos – Methyl (Actellic)	50,000 UGX per 1.5L pack
Spray logistics	
Spray pumps	800,000
Gloves – chemical resistant	20,000
Respirators	100,000
Helmet	17,000
Environmental compliance	
Soak pit and bath shelter construction	35,000 per pit
BCC and transport logistics	
Developing radio spot messages	250,000
Running radio spot messages	30,000
Radio talk show - airtime	800,000
Speakers' allowance – radio talk show	80,000
Collection of IRS supplies from other districts	3,000,000
Delivery of IRS logistics from district store to parishes	2,260,000

Source: IRS pilot and market price data

Appendix 2: Key parameters used in cost estimation

Parameter	Value
Spray Rate (SR) 1: Structures sprayed per unit pack of Pirimiphos – Methyl (Actellic)	3
Structure – SOP ratio (structures to be sprayed per SOP, per day): Spray Rate 2	8
# SOPs per spray team	5
Spray days	25
# Wash persons	2 per parish
# Stores	1 per parish
# Store keepers	1 per parish
# Security guards	2 per parish
# DHT members for supervision	15 per district
# District leaders for supervision	6 per district
# Drivers for supporting supervision	5 per district
1 pack of Pirimiphos – Methyl (Actellic)	1.5 Liters
Source: Data from IRS pilot districts	
Indirect cost of malaria to households in Uganda	7.74 US$ per malaria episode (Okorosobo et al., 2011)[2]

ENDNOTES

1 This excludes costs for Intermittent Presumptive Treatment (IPT) for malaria in pregnant women.

2 Okorosobo, F; Mwabu, G; Nabyonga, J.O; Muthuri, K.K. (2011). Economic Burden of Malaria in six Countries of Africa. European Journal of Business and Management Vol 3 #6, 2011.

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