ADDIS ABABA UNIVERSITY

COLLEGE OF HEALTH SCIENCES

SCHOOL OF PUBLIC HEALTH

ASSESSMENT OF COST, AND INVESTMENT RETURN INCLUDING HEALTH GAINS OF MALARIA CONTROL AND ELIMINATION PROGRAM IN A MALARIA HOT SPOT AREA, ABOBO, DISTRICT, WESTERN, ETHIOPIA.

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Abbreviations and Acronyms

ACT-----------------------Artemisinin-Based Combination Therapy
BSC ----------------------Bachelor of Science
CBE ---------------------- Commercial Bank of Ethiopia
CSA -----------------------Central Statistical Agency
DALY--------------------Disability Adjusted Life Year
EPSA----------------------Ethiopian Pharmaceutical Agency
ETB----------------------Ethiopian Birr
GTS-----------------------Global Technical Strategy
HCF ---------------------Health Care Financing
HEW--------------------Health Extension Workers
HIV----------------------Human Immunodeficiency Virus
HLY----------------------Health Life Year
HMIS---------------------Health Management Information System
IPT------------------------Intermittent Preventive Treatments
IRS-----------------------Indoor Residual Spray
ITN---------------------- Insecticide-Treated Net
LLIN----------------------Long Lasting Insecticide Treated Net
MDG----------------------Millennium Development Goals
MPH ---------------------Master of Public Health
MSC----------------------Master of Science
PI--------------------------Principal Investigators
RBM----------------------Roll Back Malaria
ROI-----------------------Return on Investment
RCCE---------------------Risk communication and community engagement
SBC-----------------------Social and Behavioral Changes
SDG-----------------------Sustainable Development Goals
SMC-----------------------Seasonal Malaria Chemoprevention
TB--------------------------Tuberculosis
TC -------------------------Total Cost
TFC-------------------------Total Fixed Cost
TVC-------------------------Total Variable Cost
USD------------------------United States Dollar
WHO------------------------World Health Organization
WHO-CHOICE -------------Comparing Health Outcomes in Cost Effectiveness

Abstract

Background: Malaria remains a major public health concern that places a substantial burden on health system resources. In 2024 WHO report, Ethiopia ranked among the top five countries with the highest malaria burden. Given competing health priorities, evaluating the costs and returns of continued malaria control investments is essential to sustain political and financial commitment. To achieve global malaria eradication targets by 2030, micro-level analyses are crucial to guide evidence-based policy decisions and ensure the efficient allocation of limited resources.

Method: A retrospective five-year program cost and return analysis was conducted on the cost and investment return of malaria intervention in Abobo district, western Ethiopia. Review of five-year intervention record was carried out to quantify cost and investment return associated with malaria intervention using community health planning and pricing techniques. Intervention costing was done based on micro-costing model approach using a standardized tool that categorized costs by pillars of malaria control and elimination program. Return on investment was measured by applying Return on Investment (ROI) model using Live Saved Tool (LiST) method. To assess the effects of program variation on cost and benefit, sensitivity analysis was performed. Data were analyzed using Excel and SPSS software packages.

Result: Out of the 191,829 suspected cases that were tested by RDT or microscopy, 45.5% of them were positive over a five-year period. Falciparum was predominant in an incidence of 45.74%. The expenses incurred for passive case management, vector control, and Risk Communication and Community Engagements are $1.4 to $5.5 million, $0.82 to $0.09 million, and $0.95 to $1.44 thousand, respectively. Inflation and depreciation increased uniformly across all program cost components by 26% to 27% over the study period. Correspondingly, the return on investment declined by approximately 21% to 71.7%.

Conclusion: The economic benefits derived from reduced disease burden not only enhance community health but also contribute to broader socio-economic development. Continued investment in malaria control not only saves lives but also yields considerable economic returns that can support broader health system-strengthening. The declining ROI trend observed over five years signals a need to improve program efficiency and targeting.

Keywords: Abobo, Benefits, Costs, Investment return, Malaria.

1. Introduction

1.1.Background: Malaria remains a formidable global public health challenge. Despite decades of control efforts, the disease continues to exact a heavy toll. In 2023, the World Health Organization (WHO) estimated 263 million malaria cases and 597,000 deaths globally, indicating that there were 11 million more cases of the disease in 2023 than there were in 2022. Another 600,000 people died in 2023 compared to 2022, and global incidence remains high, with an estimated 60.4 cases per 1,000 population at risk in 2023 (1).The occurrence level of malaria differs around the world. Africa continues to bear the overwhelming share of the global malaria burden, accounting for approximately 94% of all cases and 95% of deaths in 2023. The disease is deeply entrenched across the continent, with transmission occurring year-round in many regions. The majority of malaria deaths occur in young children, and the disease remains a leading cause of morbidity and mortality, particularly in rural and underserved communities (2). Despite ongoing interventions such as insecticide-treated bed nets, indoor residual spraying, and the introduction of malaria vaccines, progress towards elimination has slowed. Although Ethiopia exemplifies the complex malaria landscape in Africa. The country has one of the highest malaria burdens in sub-Saharan Africa, with about 68–75% of its landmass endemic for malaria and roughly 69% of its population at risk(3). Recent years have seen a troubling resurgence of malaria in Ethiopia. After a period of decline from 2016 to 2019, when confirmed cases and deaths fell by 47% and 58%, respectively, the country has experienced a sharp increase in cases. Between 2021 and 2022, confirmed malaria cases rose by 32.5%, from 1.1 million to 1.5 million (4). By 2023 and into 2024, Ethiopia reported over 7.3 million malaria cases and more than 1,150 deaths, marking the highest annual caseload in the past seven years(5). Abobo District is one of the districts within Gambella that experiences a high malaria burden, reporting a malaria prevalence rate of 21% among febrile patients attending health facilities in the district (6). Despite decades of progress, the disease continues to threaten millions of lives each year, making robust and adaptable malaria control strategies essential at global, regional, and national levels. The World Health Organization (WHO) developed Global Technical Strategy for Malaria 2016–2030 which sets ambitious targets for reducing malaria incidence and mortality by 90% by 2030 and eliminating malaria in at least 35 countries with pillars of malaria control programs-universal access to prevention and treatment, robust surveillance, community engagement, and health system strengthening to eliminate malaria globally, in Africa, and Ethiopia (7, 8). Global investment in malaria control has followed a pattern of scaling up intervention coverage, with annual funding requirements rising to meet ambitious targets to achieving the 2030 malaria targets is projected to require over US$100 billion, with an additional US$10 billion for research and development of new tools, annual investments are estimated $8.7 billion by 2030(9). Notably, the 20 countries with the highest malaria burden will require the majority (88%) of these resources (8). Investment strategies prioritize expanding access to core interventions in high-burden areas, supporting innovation in diagnostics, treatments, and vector control, strengthening surveillance and response systems, and ensuring efficient use of resources given funding constraints (8). Returns on malaria investments have been substantial, both in health and economic terms. Health gains since 2000, malaria incidence has dropped by nearly 30% globally, and mortality has fallen by 47% (9). Investments have averted over 1.3 billion cases and saved more than 10 million lives, with the majority of benefits seen in sub-Saharan Africa(10).In addition, economic gains of malaria control are approximately US$152 billion across 26 high-burden countries, equivalent to 0.17% of total GDP over the study period (11). These gains are realized through increased productivity, reduced health system burden, and improved educational outcomes, particularly as fewer children and adults fall ill and miss work or school (11). Despite ongoing efforts to implement malaria control and elimination programs, there is a critical need to evaluate the benefits of the intervention in terms of cost benefits and health outcomes. Understanding the economic implications and health gains associated with the program is essential for optimizing resource allocation and ensuring sustainable malaria management strategies. However, there is no previous information on the resource allocation situation of the malaria control program in the district. Thus, the information generated from this study helps to strengthen the local malaria control program by informing resource allocation decisions by characterizing the current resource allocation situation and identifying the best allocation method that considers the context.

1.2. Statements of the problem

Malaria remains a significant public health challenge in 94% of the cases, and 95% of deaths a burden occur in the African region, particularly in sub–Saharan Africa. Ethiopia is part of sub-Saharan Africa, particularly in the Abobo district, identified as a malaria hotspot facing a high burden of malaria cases. Where environmental changes and socio-economic factors have exacerbated the transmission dynamics, migration from the malaria-free highland region to the Malarias lowland of Abobo significantly increases malaria risk. Migrants often lack immunity to malaria and may not have access to preventive measures or health services. Settles in irrigation areas, which typically have lower socioeconomic status, are particularly vulnerable due to poor housing conditions that facilitate mosquito breeding, limited access to insecticide-treated nets (ITNS), and treatment options (12). Environmental conditions play a critical role in malaria transmission. Stagnant water bodies, which serve as breeding grounds for Anopheles mosquitoes, are prevalent in Abobo. The presence of garbage heaps and inadequate drainage systems further exacerbates the situation, increasing the likelihood of malaria transmission (13, 14). Additionally, climatic changes, such as fluctuations in rainfall and temperatures, have been linked to increasing malaria incidences in the districts (13). Access to healthcare services is a major concern in Abobo. Many health facilities struggle with inadequate resources and are often located far from communities, particularly in conflict-affected areas. This leads to delays in diagnosis and treatment, contributing to higher morbidity and mortality rates associated with malaria. Despite efforts to distribute ITNs and implement indoor residual spraying (IRS). Coverage remains inadequate. Many households do not utilize these preventive measures effectively, either due to a lack of awareness or insufficient resources(14, 15). Malaria disproportionately affects working-age populations, leading to absenteeism from work due to illness. Malaria-related absenteeism could result in a loss of productivity valued at millions of dollars annually in Ethiopia(16). High malaria prevalence places an immense burden on healthcare facilities, diverting resources away from other essential health services. This strain can lead to increased wait times and reduced quality of care for other diseases (17). Recurrent malaria infections can lead to chronic health issues, including anemia and impaired cognitive development in children. These long-term effects may hinder educational attainment and future economic opportunities(18). The cost of ITN distribution in Ethiopia was approximately $5 per net, with additional costs for training personnel and conducting awareness campaigns (19). The cost of rapid diagnostic tests(RDTs) can range from $0.50 to $2.00 per test, while Artemisinin-Based Combination Therapy (ACTs) can cost between $1 and $10 per treatment course, depending on procurement strategies (20). In rural areas, where access to healthcare services is limited, the cost of transportation to health facilities further exacerbates financial burdens on families(21).

Moreover, the emergence of a new mosquito species, Anopheles stephensi, complicates vector control efforts as they adapt well to the urban environment, thereby increasing transmission risks even in areas with existing control measures (22). Investments in malaria control are substantial but necessary. According to estimates reducing malaria case incidence and mortality risk by 90% globally by 2030 will require approximately $100 billion for interventions, alongside an additional $10 billion for research and development of new treatments and technologies, $4.40 per person at risk, $7.7 billion (95% UI $5.4–$10.9 billion) by 2025 and $8.7 billion (95% UI $6.0–$12.3 billion) by 2030 (23). Despite ongoing efforts to implement malaria control and elimination programs, there is a critical need to evaluate the benefits of the intervention in terms of cost benefits and health outcomes. Understanding the economic implications and health gains associated with the program is essential for optimizing resource allocation and ensuring sustainable malaria management strategies. There is an urgent need to systematically assess the cost and investment return of malaria control and elimination in Abobo. This assessment provides valuable insight into the benefits of current strategies and informs future investment aimed at reducing malaria morbidity and mortality in this high-risk area.

1.3.Significance of the study

The findings of this study generate knowledge and give insight into the Assessment of cost and investment return, including health gains of malaria control and elimination programs in a malaria hot spot area, Abobo, Ethiopia. The findings can inform national and regional health policies by providing evidence-based recommendations for future malaria control strategies as Ethiopia aims for nationwide malaria elimination by 2030. It aids in identifying which strategies are most effective and will provide insights into the health gains achieved through malaria control efforts. Analyzing the specific health outcomes in this region can help tailor interventions to local needs, potentially leading to more effective strategies that address unique epidemiological challenges

2. Literature review

2.1.The Global Funding

Malaria control can be viewed as a public good, characterized by non-excludability and non-rivalry. This theory posits that because individuals cannot be excluded from benefiting from malaria control efforts, there is often underinvestment in these initiatives by private entities. Because of the Market Failure Theory, the private market fails to provide sufficient funding for malaria control due to high costs and low profitability. Global Governance Theory emphasizes the role of international institutions and collaborations in mobilizing resources for global health issues play pivotal roles in coordinating funding efforts and ensuring accountability. Hotspot refers to a geographical area exhibiting significantly higher transmission intensity of malaria compared to surrounding regions. Low Transmission Period Hotspots (LT Hotspots), defined as villages that reported at least one malaria case during the low transmission season (December to May). They indicate areas where malaria transmission persists even during periods of generally low incidence. High Transmission Period Hotspots (HT Hotspots), characterized by the highest malaria incidences during the peak transmission season (June to November). They represent areas where malaria cases surge, necessitating focused intervention strategies. High Connectivity Hotspots (HC Hotspots) features are Villages that are highly interconnected with neighboring areas based on human mobility, and are classified as HC hotspots (24, 25). Malaria control strategies have been at the epicenter in tackling and reducing the global burden of communicable diseases. It took almost 30 years from the end of the Global Malaria Eradication Program (1969-2000), this period was characterized by a sense of failure and abandonment in the fight against malaria (26).

In 1998, a renewed malaria control campaign was launched, the Roll Back Malaria (RBM) (27). The first 2 decades of the 21st century represented a golden era in the history of malaria control. The world pulled together to fight malaria, delivering one of the biggest returns on investment in global health. The unprecedented scale-up of malaria interventions over this period has led to considerable reductions in disease incidence and mortality. It was estimated that malaria case incidence had reduced by 37% and mortality rate by 58% between 2000 and 2015 (28). These major declines in the malaria burden were considered conclusive evidence of achieving, or even surpassing, the MDG target 6C, and were hailed as showing the remarkable strides that could be made with adequate investment and political commitment (26). The lack of sufficient evidence on country-specific costs and intervention effectiveness complicates efforts to optimize resource allocation; Mathematical models have been employed to assess various intervention strategies' efficiency under constrained budgets, emphasizing the need for tailored approaches that consider local contexts (29). The evolution of global funding for malaria control over the past two decades. According to the World Malaria Report 2021, global funding for malaria reached approximately $3 billion in 2020, a significant increase from $1 billion in 2005. A systematic review found that increased funding for malaria interventions was associated with significant reductions in malaria incidence and mortality rates. Countries that received substantial international assistance demonstrated faster progress toward elimination compared to those with limited funding (30). In Rwanda, the introduction of ITNs and rapid diagnostic tests (RDTs) funded by international donors resulted in a reported 75% decrease in malaria cases between 2005 and 2015. Among the global malaria community, there was no consensus on the need to develop a coherent and even more ambitious global strategy, ergo the development of a Global Technical Strategy (2015). The Strategy set ambitious but achievable goals, with five-year milestones leading to the 2030 targets that aim to reduce malaria incidence and mortality rates by at least 90%, interrupt malaria transmission in at least 35 countries, and prevent its re-establishment in all malaria-free countries, consistent with SDGs. The annual investment will need to increase to an estimated total of US$ 7.7 billion per year by 2025 and US$ 8.7 billion by 2030(23). Despite significant increases in funding, challenges remain regarding the equitable allocation of resources. A study shows high disparities in funding distribution across regions and populations. Low-income countries often face difficulties accessing funds due to bureaucratic hurdles and a lack of capacity to implement large-scale programs (31). In addition, a critical issue is the sustainability of funding. Many countries rely heavily on external funding sources. Research indicates that fluctuations in donor contributions can lead to program disruptions, hindering progress toward elimination goals. Further, external factors such as the COVID-19 pandemic have strained health systems and diverted resources away from malaria programs. This trend raises concerns about reversing gains made over previous decades if sustained investment is not maintained (32).

2.2.The impact of malaria control measures

Despite substantial progress in reducing malaria morbidity and mortality, the disease continues to pose a major threat to global health, particularly in sub-Saharan Africa. According, the ecological model highlights the importance of controlling mosquito populations through methods such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and environmental management is aimed at reducing the transmission of malaria by decreasing the vector population or limiting human-vector contact (33). The model also underscores the role of effective treatment in reducing malaria morbidity and mortality. Artemisinin-based combination therapies (ACTs) have been recommended as the first-line treatment for uncomplicated malaria. The timely diagnosis and treatment of malaria cases can prevent severe illness and reduce transmission(34). Community involvement is crucial for the success of malaria control measures. Educational interventions that raise awareness about malaria prevention and treatment can empower communities to adopt protective behaviors (35). A systematic review found that the widespread distribution and use of ITNs significantly decreased malaria incidence in several African countries. In Nigeria, the introduction of ITNs was associated with a 50% reduction in malaria prevalence among children under five (36).IRS has also been shown to be effective in reducing malaria transmission. A study in Uganda demonstrated that IRS implementation led to a 43% reduction in malaria cases compared to areas without IRS(37). However, the effectiveness of the IRS can be influenced by factors such as insecticide resistance among mosquito populations (38). Environmental management strategies, such as larval source management and habitat modification, have been shown to reduce mosquito-breeding sites. A study in Kenya indicated that integrating environmental management with ITNs resulted in a 30% decrease in malaria incidence compared to ITNs alone (39). Even though all interventions are applied, the resources are a critical issue for the elimination of malaria. In the context of scarce financial resources and additional pressing public health priorities, international organizations and government policymakers are faced with key economic questions, such as what the costs of the implemented interventions are and whether they are economically justified. From 2006-2010, US$8.9 billion was disbursed for malaria control and elimination programs. Africa had the largest levels of funding per capita-at-risk, with most nations supported primarily by international aid (40). WHO's Choosing Cost-Effective Interventions (WHO-CHOICE) program, released a 2021 update, showed that cost-effectiveness ratios less than I$ 100/HLY saved for virtually all interventions on HIV, TB, and Malaria (41). In sub-Saharan Africa, it is estimated that malaria control interventions accounted for 70 % of the 943 million fewer malaria cases occurring between 2001 and 2015, averting 663 million malaria cases. It is estimated that 69% of cases averted were due to ITNs, 21 % due to ACT, and 10 % due to IRS. A 2021 systematic review of 103 costing studies, mainly from Tanzania, Zambia, and Ghana, resulted in the economic cost of protecting 1 person per year ranging from $1.18 to $5.70 with vector control, $0.53 to $5.97 with chemoprevention, and the economic cost per case diagnosed with rapid diagnostic tests was $6.06 and per case treated $9.31 or $89.93 depending on clinical severity (42).In Mozambique a 2016 cost-effective study was done on a malaria elimination initiative project, resulting in averting a total of 3,171 DALYs at an incremental cost of $2.89 million and an average yearly cost of $20.7 per targeted person, which proved to be a cost-effective strategy to drastically reduce transmission in areas of low to moderate transmission in Sub-Saharan Africa (43). Likewise, an extended cost-effectiveness analysis done in Ethiopia(2020) found were ACT, LLIN, IRS, and vaccine would avert 358, 188, 107, and 38 deaths, respectively, each year at a net government cost of $5.7, 16.5, 32.6, and 5.1 million. The four interventions, ACT and LLINs, having the largest impact, would eliminate about $4,627,800 of private health expenditures, and the poorest income quintiles would see the greatest FRP benefits (44). A systematic review indicated that the extensive distribution of LLINs has significantly contributed to a reduction in malaria cases, with estimates suggesting that 67-73% of malaria cases averted in sub-Saharan Africa since 2000 can be attributed to their use (45). The effectiveness of LLINs is contingent upon consistent usage. Factors such as discomfort due to heat retention and lack of awareness about their protective benefits can lead to reduced utilization (46). Evidence suggests that IRS can significantly reduce malaria transmission; for instance, studies in Tanzania demonstrated a protective efficacy of 54% against reinfection following treatment. Furthermore, IRS has been shown to reduce malaria incidence rates by up to 88% in certain contexts (44).Despite the remarkable progress made by the global control strategies, there are limited financial resources to scale up malaria control interventions to reach the targeted international goals. The aim to cover over 80% of currently available interventions needs to increase substantially above the current annual spending of about US$ 3.0 billion. While this total greatly exceeds current investments, malaria interventions are highly cost-effective and exhibit one of the highest returns on investment in public health. Moreover, the cost, the funding gap between the amount invested and the resources needed, has continued to widen significantly (29).

3. Objectives

3.1. General objective

- ✓ To assess the cost, investment return, and health gains of malaria control and elimination program in a malaria hot spot area, Abobo, District, western, Ethiopia.

3.2. Specific objectives

- ✓ To assess the cost of malaria control and elimination program in Abobo, District, Western, Ethiopia.
- ✓ To assess the investment return of malaria control and elimination program in Abobo, District, Western, Ethiopia.
- ✓ To assess the health gain from the malaria control and elimination program in Abobo, District, Western, Ethiopia.

4. Methods and Materials

4.1. Study area and period

The study was conducted in one of the province towns, Abobo, Gambella, Ethiopia, which is located in northwestern Gambella city bordering South Sudan, and one part of the Anuak zone. The town lies along the Baro River, and the Alaro irrigation dam, which is significant for transportation, fishing, and agriculture in the area. Cereal (maize, sorghum, and rice) and fruits (mango, papaya, and banana) are the main agricultural products in the area. It is about 800km, and 42 km away from the capital cities of Ethiopia, Addis Ababa, and Gambella regions, respectively. Lies on a latitude of 8.25° N and longitude of 34.55° E. It has a tropical savanna climate, characterized by distinct wet and dry seasons. The average annual temperature typically ranges from 20°C (68°F) at night to around 30°C (86°F) during the day. The wet season usually occurs from June to September, with heavy rainfall that can lead to flooding in some areas. The dry season typically runs from October to May, during which temperatures can be higher and humidity lower. In addition, there are functional health institutions: sixteen health posts and four health centers. The area is known for its high prevalence of malaria. It has mainly two types of nations, Anuak and Nuer, with various smaller ethnic groups. It has an estimated population of more than 30,413. The study was conducted from February 2025 to March 2025, and data were collected for two consecutive months. The estimated total population of Abobo District is 30,413, of which 52% are female. 26% are women of reproductive age, 3% are pregnant women, 2.8% are infants under one year of age, 14.2% are children under five, and 5.5% are elderly individuals. *(Source: Personal communication, Abobo Health Office.).*

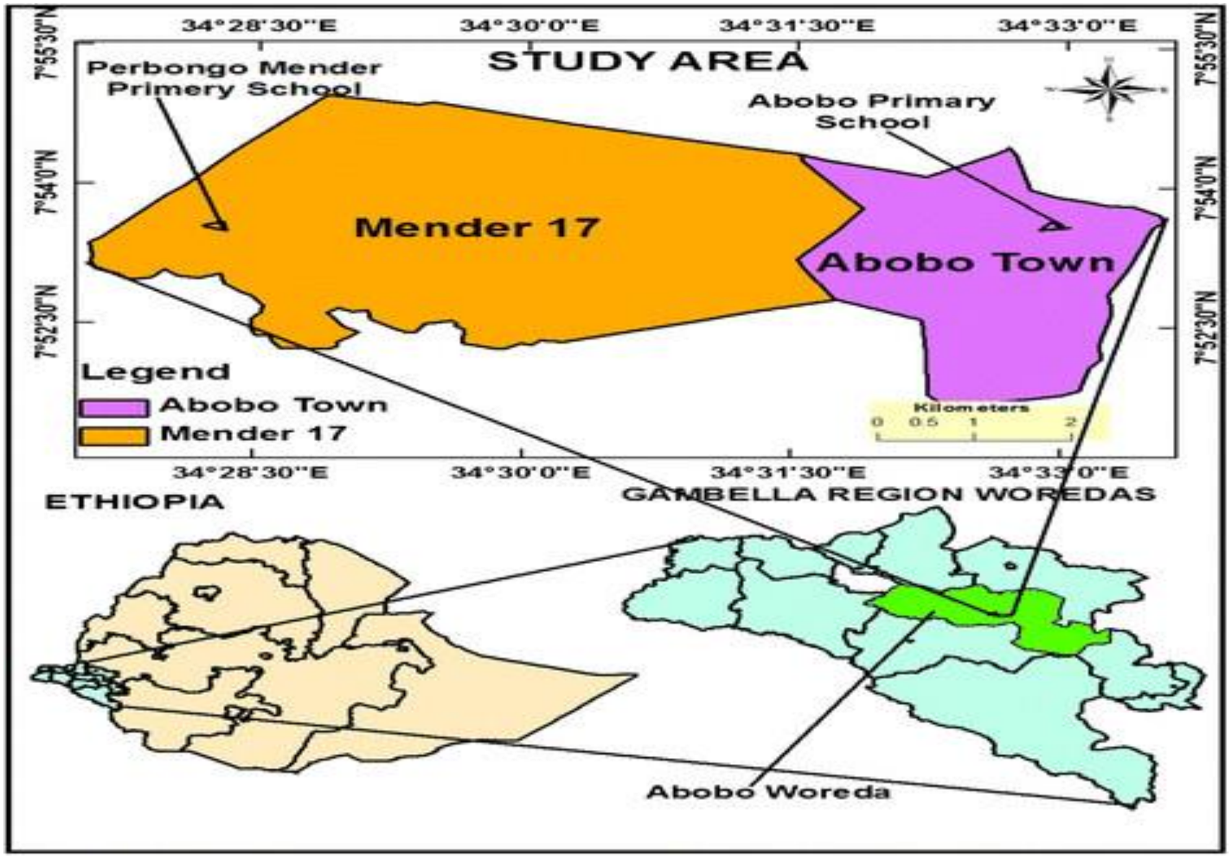

Figure 1: Maps of Abobo Districts, Ethiopia

4.2. Study design:

A cross-sectional study design was used to quantify every input that goes into the pillars of local malaria control program based on a bottom-up micro-costing model. Cost was estimated by applying a standard costing procedure. A five-year program cost and case data were collected using standardized questionnaires to calculate the return on investment.

4.3. Population

4.3.1. Target population:

All types of public health facilities and public health offices in the Gambella region were the target population for the study.

4.3.2. Source populations

All health program managers, facility leaders, financial managers, pharmacists, health care professionals, World Bank Data, World Health Organization, and high-level experts were the source population for the study.

4.3.3. Study population

All health facilities and health offices were included in the actual sample study.

4.3.3. Study unit

Individual facilities involved in the actual study were the study units of the study.

4.4. Sample size

All health facilities and administrative health offices in Abobo District were included in the study.

4.5. Sampling Procedure

The study was conducted in all of the public health facilities and administrative health offices in Abobo District. All distributed drugs, reagents, chemicals, capacity building and training costs, prevalence and incidences, malaria prevention costs, and promotion costs, and all the necessary data for the costs, investments, and benefits of malaria elimination and control program were collected from the districts, regional government, federal ministry of health, World Bank data bases~~,~~ (WB), and World Health Organization (WHO).

4.6. Operational definitions

- ✓ **Death Averted (Lives Saved):** The number of malaria-related deaths estimated to have been prevented due to implementing malaria control interventions within a specified timeframe. This is typically calculated using epidemiological models that consider factors such as malaria incidence rates and mortality rates (47).
- ✓ **Fiscal multipliers** are economic indicators that measure the impact of government spending or taxation changes on overall economic output, typically represented as a change in Gross Domestic Product (GDP). Specifically, a fiscal multiplier quantifies how much additional economic activity is generated from an initial change in fiscal policy (48). The World Health Organization (WHO) estimated that a malaria control program could create an average of 0.0022 jobs for every $1(112 birr) spent.
- ✓ **Health gain**: Reduced morbidity and mortality by implementing malaria control and elimination programs in districts in specific periods (49).

4.7. Costing:

4.7.1. Perspective

A study was used from a provider perspective to estimate the cost and investment return of the malaria control program in Abobo District, Ethiopia.

4.7.2. Cost type

The recurrent and capital cost was estimated from the provider perspective because the health facilities and administrative offices are the providers of health care deliveries, so the cost type of the study was provider cost.

4.7.3. Unit of Costs

This study used the median cost of input resources such as medicines, medical supplies, chemicals, reagents, and medical equipment from the Ethiopian Pharmaceutical Supply Services procurement list of drugs and medicines, and the median cost for non-medical equipment and consumables was taken from the purchase price of financial receipts.

4.7.4. Costing Scope:

The study clearly defined the perspective, cost objective, cost category, cost types, and the time horizon appropriate for the perspective of the cost study.

4.7.5. Costing approach

This study used a cross-sectional cost approach of the bottom-up micro-costing methodologies to quantify every input consumed and to allocate the average cost expenditures of the malaria control strategies. Excluding utility and opportunity costs. The productivity of the population is not similar, which makes it difficult to calculate opportunity costs, and there is a difference in the utility of services like water supply and electricity makes it difficult to calculate the utility costs.

4.7.6. Time horizon:

The study clearly defined that the length of the study is a five-year study to capture all costs relevant to the malaria control and elimination intervention program.

4.7.7. Costing Measuring Units

The study used first the Ethiopian birr (ETB), and then, for international comparison, it was converted to USD to estimate the direct economic cost and the investment return of the malaria elimination programs.

4.7.8. Price data source, pricing, and valuation

The Commercial Bank of Ethiopia (CBE), Ethiopian Pharmaceutical Supply Services (EPSS), and World Bank databases, the Gambella Health Bureau Plan and Finance Office, the Gambella Health Bureau Health Care Financing Unit (HCF) units, the human resource department, and the primary data collected were the cost data agents. The total variable cost (TVC) and total fixed costs were calculated for all health facilities and administrative offices.

4.7.9. Discount and inflation, currency conversion rate

The study used a 3% discount rate for depreciation costs analysis for capital costs (50), and 26.6% inflation for medicines, reagents, chemicals medical equipment, drugs, medical supplies, and non-medical cost items deployed to adjust the price equivalence 2024 for, chemicals, medical laboratory reagents, equipment, and non-medical equipment(51). The study used the median unit price of all cost items to remove any outliers, and the conversion rate was 1 US dollar equivalent to 112 Ethiopian birr (1 USD =112 ETB), Thursday, 10 October 2024, in the Commercial Bank of Ethiopia (52).

4.7.10. Sensitivity analysis

One-way sensitivity analysis was limited to testing assumptions on depreciation and inflation to show their impact on cost and ROI with a tornado diagram.

4.8. Costs Included in Studies

The malaria control and elimination programs for the malaria intervention models/pillars direct cost.

- ✓ Passive Case detection (routine diagnosis and treatment in health facilities and the community).
- ✓ Vector Control (Distribution of LLINs, IRS Seasonal malaria chemoprevention (SMC), and Intermittent preventive treatment (IPTp).
- ✓ Capacity building (system strengthening, human resources training, review meetings, mentorship)
- ✓ Risk communication and community engagement (RCCE)

- ✓ Investment return costs
- ✓ Personal costs
- ✓ Consumable costs
- ✓ Capital costs

4.9. Benefits tool

The benefits of the components of the community health-planning program include insurance, productivity, and employment.

4.9.1. Insurance component contains

- Economic impacts of malaria were assessed by asking about the total costs incurred by the occurrence of the epidemic.
- Years over which malaria could occur as epidemics, the time taken for the occurrence of epidemics.
- Annual economic risk from malaria: the ratio of (economic impact of malaria/ years over which malaria could occur as epidemics)
- Size of the total health workforce: the total health workforce in the districts.
- Number of health working forces on the interventions; the added health workforces during the intervention.
- Percentage increase in districts' health workforces; the ratio of (number of health working forces on the interventions*100/size of the total health workforces.
- Annual values of health working forces contributed to a reduction of malaria economic risks;   annual economic risk from malaria *percentage increase in districts' health workforces.

4.9.2. Productivity components contain

- GDP per capita: the GDP of each year
- GDP per capita growth rate for each year
- Life expectancies for each year
- Average ages entering in labor force

- Productive years regained; the differences of each year (life expectancies – average ages entering the labor force).
- Benefits per death avoided: the sum of productive years regained of each age in each year.
- Death averted; the differences between the deaths and cases of malaria in each year.
- Total benefits productivity; benefits per death avoided each year, *deaths averted each year.

4.9.3. Employment components

- Total costs: the total costs of the interventions in each year will be taken from the cost tools
- Fiscal multipliers quantify how much additional economic activity is generated from an initial change, i.e., if you spend $1000, you will, on average, create 2.25 jobs.
- Total employment ; total costs * fiscal multipliers = total costs * 0.0022
    - **Finally, the total benefits are**: benefits (insurances + productivity + employment).

The local malaria control program cost was estimated using community health planning and costing tools. The tool is widely used for planning and costing community health program packages. The data needed to calculate the cost was obtained from the World Bank data source, the Gambella region health office, and the Ministry of Health. After knowing the cost of the malaria intervention program, Live Saved Tool (LiST) software was used to calculate the return on investment (ROI) based on an economics model of Cost and benefit, also ROI is calculated by assumptions principles based on the Centers for Disease Control, and Prevention (CDC), (53, 54). Framework for Program Evaluation in Public Health, and a Framework for Program Sustainability. The principles are strong supervision, monitoring and evaluation, needs assessments, clear Objectives, Evidence-based practices, Stakeholder engagements, cultural competencies, Flexibility and adaptability, Sustainability, and Training and support.

4.10. Return on investments

Return on investment is a type of cost-benefit analysis in malaria control and elimination interventions, which was assessed by the ratio of the benefits to costs. Then, after knowing the return on investments of the intervention, give the conclusion by comparing it with the different papers on the intervention of the programs.

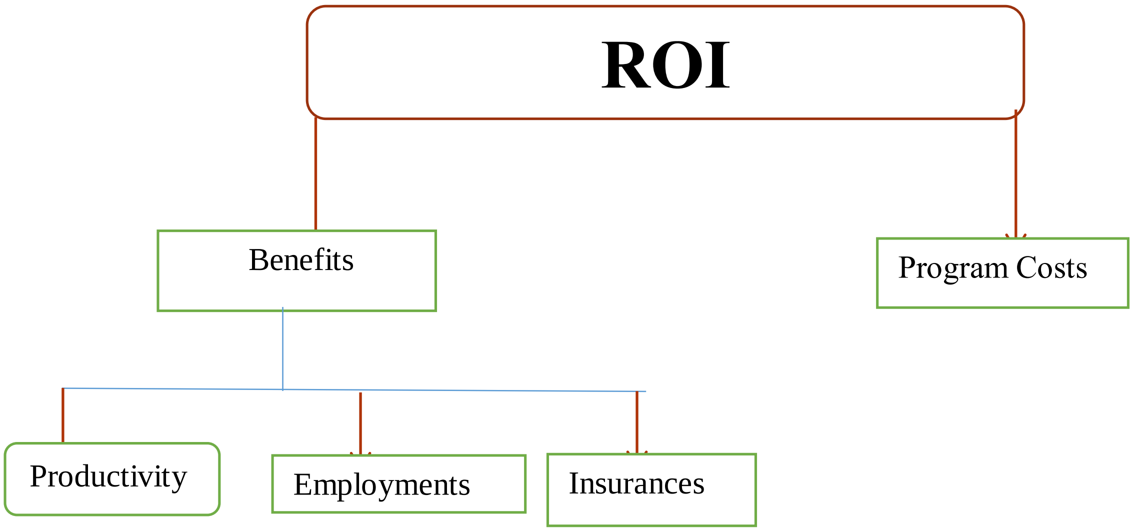

Figure 2: ROI model

4.11. Data Quality Assurance Procedures:

The ability to collect high-quality data to meet the expectations of the study objectives is of paramount importance. Towards this end, experienced supervisors and data collectors familiar with the health system and health facilities were mobilized and deployed. The quality of data was further ascertained during data collection, data entry, and data cleaning. A team of experts was strictly supervising the data entry process during the entire period of data entry. Each quantification tool and cost center was strictly cleaned to avoid double-counting and missed values, so that unlikely values were rejected. Re-evaluation and judgments on the rejected responses were made. Finally, all entered data was further visually checked for outliers. Data was adjusted for depreciation and inflation.

4.12. Training of data collectors;

Training on the objectives of the malaria control and elimination program cost quantification, benefits tools, and questionnaires was provided to the team of data collectors and supervisors.

4.13. Costing tool validity

The validity of this tool was tested and widely used for planning, costing, and benefits of community health program packages in many countries for malaria control and elimination programs.

4.14. Data Management and Analysis

The costs of the objects were assessed using community health planning costing, and benefits tools important cost indicators like the cost of case management, costs of vector control, cost of capacity building, cost of community empowerment, and engagement, personal costs, and other costs was calculated, and corresponding benefits of insurances, productivity, and employments. The return on investment objective was assessed by using the Live Saved Tool (LiST), and the health gain objective was assessed by components of costs of health planning costing tools in each year of the intervention, by knowing the mortality and morbidity of malaria. Then, the data on malaria cases record of different health institutions of the study site was transferred to an Excel spreadsheet and checked for completeness. After that, the data were analyzed descriptively using SPSS software.

4.16. Indicators

The study used the indicators from revised national HMIS malaria indicators to show the impact of malaria control and elimination programs in Abobo District, Ethiopia, and the following are among the indicators based on the malaria prevention pillars.

- ✓ Malaria positivity rate.
- ✓ Proportion of confirmed malaria cases fully investigated and classified.
- ✓ Proportion of units of structures covered by indoor residual spraying.
- ✓ LLITN distribution coverage to malaria risk population and utilization.
- ✓ IRS Utilization coverage

4.17. Ethical considerations:

After approval of the proposal by Addis Ababa University School of Public Health, Departments of Health Management, and Police Unit of Health Economics Research and Ethical Review Committee, clearance letters were written to the Abobo health bureau. The data collectors explained the objective of the study and confidentiality ahead of each interview. The probability and magnitude of harm or discomfort anticipated in this study are nonexistent. Hence, an ethical approval letter was secured from Addis Ababa University before the start of the actual data collection.

5. Result

5.1. Socio-demographics of the district

Across the five years, a total of 87,321 malaria cases were reported, with 44,536 cases among females. The majority of cases occurred in individuals aged ≥15 years, followed by those aged 5–14 years, while children under five consistently exhibited the lowest case counts. Annual case numbers fluctuated markedly, with substantial increases observed in 2021 and 2022 before declining in 2023. *Plasmodium falciparum* accounted for most infections (76,726 cases), whereas *P. vivax* contributed 10,595 cases, indicating a strong predominance of *P. falciparum* transmission in the district.

Table 1: Distribution of malaria cases by age and sex in Abobo district, Western Ethiopia.

Years	Age in years	Male	Female	Total	Falciparum	Vivax
2019	<5	666	694	1360	1195	165
	5—14	1290	1344	2634	2315	319
	≥15	2735	2818	5553	4879	674
2020	<5	484	505	989	867	122
	5—14	939	977	1916	1683	233
	≥15	1977	2080	4057	3567	490
2021	<5	1507	1570	3077	2706	371
	5—14	2920	3040	5960	5237	723
	≥15	6152	6405	12557	11033	1524
2022	<5	1959	2039	3998	3513	485
	5—14	3794	3949	7743	6803	940
	≥15	7994	8321	16315	14336	1979
2023	<5	1477	1559	3036	2667	369
	5—14	2862	2979	5841	5132	709
	≥15	6029	6256	12285	10793	1492
	Total	42785	44536	87321	76726	10595

5.2. Malaria morbidity, mortality, and intervention

In the last five years (from 2019 to 2023), malaria surveillance data revealed a consistently high disease burden across all age groups, with adults aged 15 years and above being the most affected. Of the total confirmed malaria cases reported over the five years, 51% were females, and adults accounted for 58.1% of all cases, highlighting a significant vulnerability among the working-age population. Children aged 5–14 years contributed 27.6% of the cases, while children under five made up the remaining 14.3%.

Plasmodium falciparum, the most virulent and deadly malaria parasite, overwhelmingly dominated the infections, accounting for 87.9% of all confirmed cases, while *P. Vivax* represented 12.1%. The years 2021 and 2022 saw the highest number of *P. vivax* cases, aligning with an overall increase in malaria transmission. The peak occurred in 2022, which not only recorded the highest total number of confirmed malaria cases, but also saw *P. falciparum* comprising 82.16% of infections. That year, the test positivity rate reached 52.17%, and the incidence rate climbed to a staggering 97.88%, reflecting intense transmission and disease pressure across the population. Despite these high caseloads, no malaria-related deaths were reported during the entire period, suggesting effective case management and strong intervention measures.

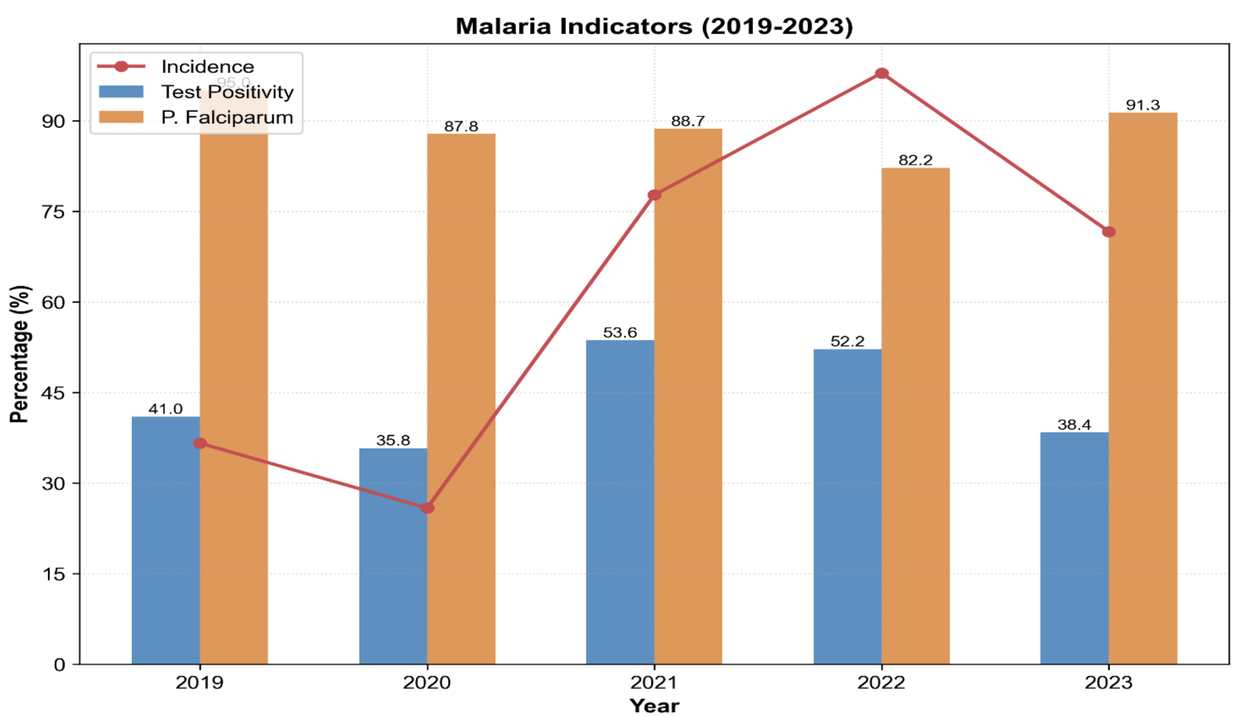

Figure 3: Malaria cases in Abobo district, Western, Ethiopia.

From 2019 to 2023, indoor residual spray (IRS) coverage in the district showed consistently high levels, reflecting strong implementation of malaria vector control interventions. Coverage increased steadily from 85% in 2019 to 87% in 2020, followed by a significant jump to 94% in 2021. Although there was a slight decline to 91% in 2022, the coverage rose again to 93% in 2023.

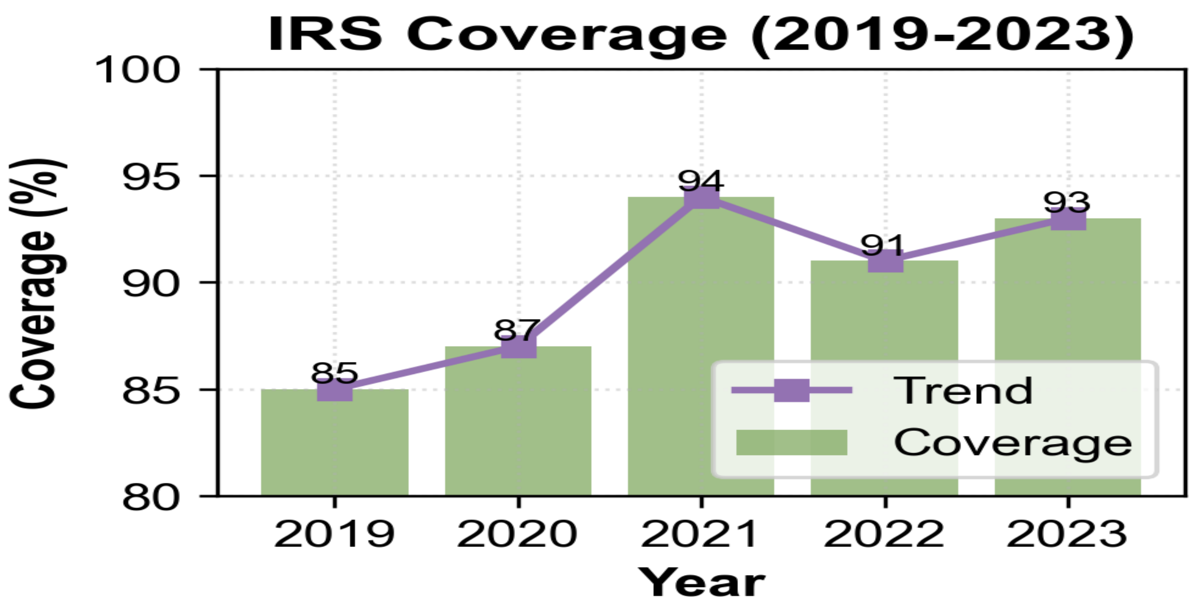

Figure 4: The indoor residual spray coverage in Abobo district, Western, Ethiopia.

Between 2019 and 2023, a district experienced a notable fluctuation in the number of confirmed malaria cases across both outpatient and inpatient departments. In 2019, the district reported a total of 9,547 confirmed cases, with 9,270 cases managed in outpatient departments. The following year, 2020, saw a decrease to 6,961 total confirmed cases, comprising 6,774 outpatient cases. In 2021, the district experienced a significant surge, with total confirmed cases rising to 21,594, 21,138 in outpatient departments. This increase could be linked to a resurgence of malaria cases following the initial pandemic-related disruptions. The trend continued upward in 2022, reaching a peak of 28,056 total confirmed cases, with 27,705 in outpatient. In 2023, the total confirmed cases slightly decreased to 21,162, with 20,859 in outpatient departments. While this decline is encouraging, the numbers remain significantly higher than in 2019.

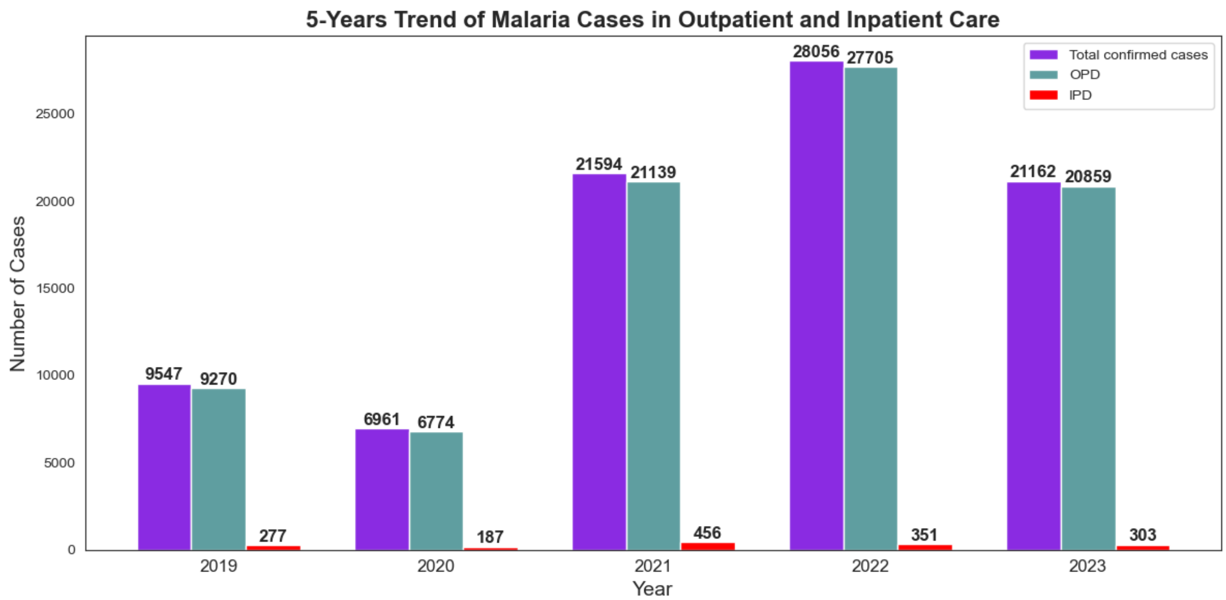

Figure 5: total number of confirmed cases by outpatient and inpatient departments in Abobo, district, Western Ethiopia (2019-2023).

5.3. Cost of Malaria Control Program

Malaria program cost in the Abobo district included direct and indirect costs from government and non-governmental budget sources. The direct costs associated with the malaria control and elimination program encompass a wide range of expenditures**.** The key components of the direct costs for malaria control and elimination program from the provider's perspective included costs related to management of malaria cases, costs of vector control, capacity building activities, and personnel. The costs associated with passive case detection had fluctuated significantly over the five years, with notable costs of $2.1 million and $1.4 million in 2019 and 2020, respectively. A sharp increase in case management costs was observed in 2021, reaching over $4.6 million. The cost peaked in 2022, investing approximately $5.5 million, while there was a slight decline to about $4.6 million in 2023.

The vector control costs included expenditures on long-lasting insecticide-treated nets (LLITNs), indoor residual spraying (IRS), and other vector control measures. A significant drop in cost was noted from around $0.4 million in 2019 to $0.09 million in 2020, indicating a possible reduction in vector control activities. However, costs surged to nearly $0.82 million by 2023. The efforts to educate communities about malaria prevention and treatment saw an increase in expenditure from about $0.95 thousand in earlier years to over $1.44 thousand by the end of the period. Personnel costs included salaries and wages for healthcare workers involved in malaria control efforts. Media and education costs were expenses related to public health campaigns aimed at raising awareness about malaria. Supplies and furniture costs included expenses related to the purchase of medical supplies and equipment necessary for effective intervention. Unlike the costs of case management and vector control, the other cost categories exhibited a consistent overall pattern over the five years. Capital goods were annualized based on their useful life years and a standard discount rate of 3% from WHO CHOOSE.

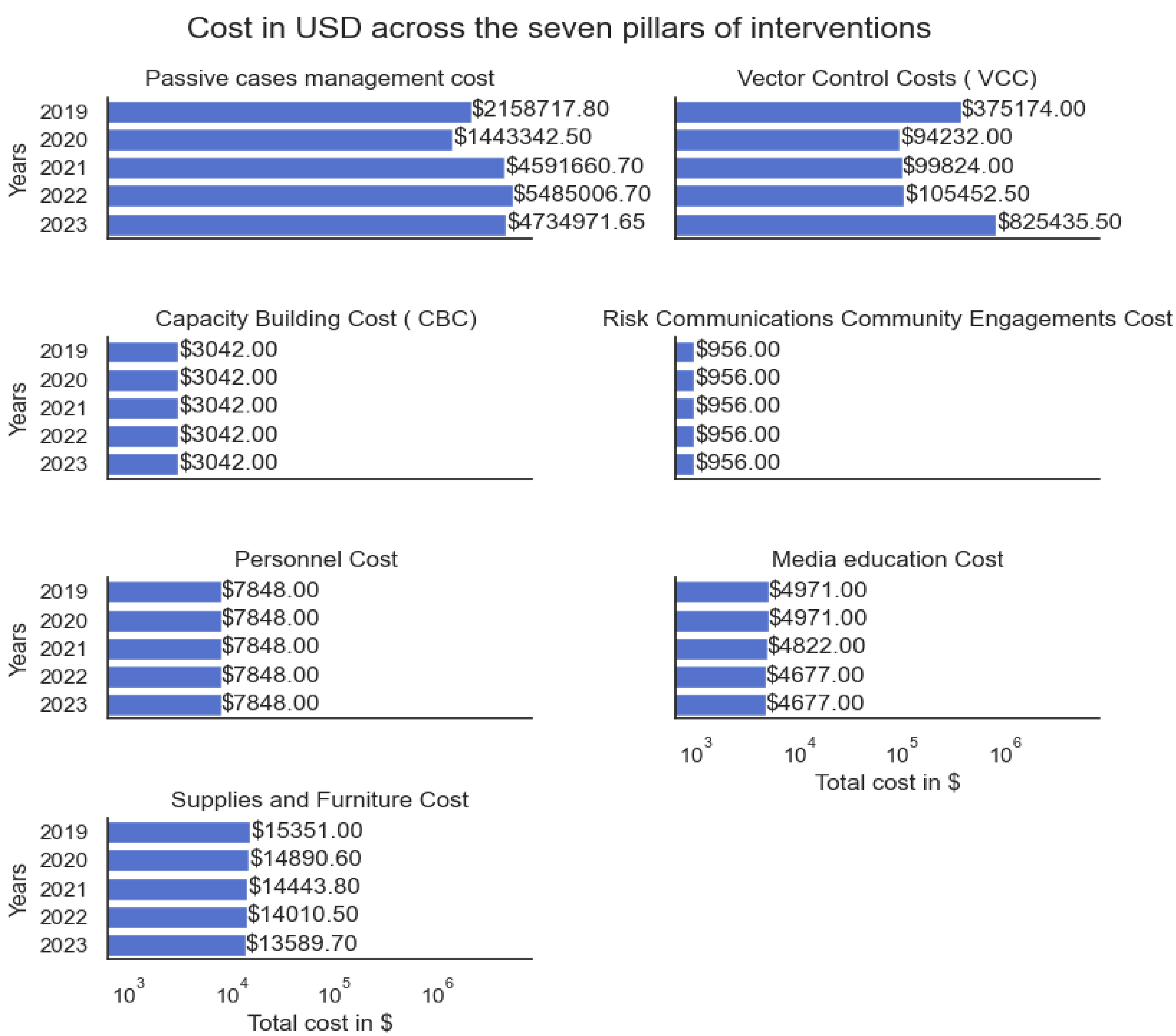

Figure 6: Cost distribution by year across the seven pillars of malaria intervention in Abobo district, Western, Ethiopia. 2019-2023.

During the intervention period from 2019 to 2023, investment in malaria control demonstrated a strong correlation with the trends in confirmed malaria cases, reflecting a responsive and adaptive approach to disease management. Expenditures increased steadily from $2.56 million in 2019 to a peak of $5.62 million in 2022, in direct response to rising malaria incidence, particularly during the high-transmission years of 2021 to 2023. In 2021, a sharp rise in confirmed cases to 53.64% was met with an increased investment of $4.72 million. The following year, 2022, marked the highest malaria burden, with 52.17% of tested individuals confirmed positive, prompting the highest investment outlay of $5.62 million, the intensity of control and treatment efforts required during peak transmission. Although confirmed cases declined to 38.4% in 2023, investment remained high at $5.59 million, signaling a strategic commitment to sustaining gains and preventing resurgence. In contrast, 2020 recorded both lower case rates and the lowest spending at $1.56 million, consistent with a relatively reduced transmission year.

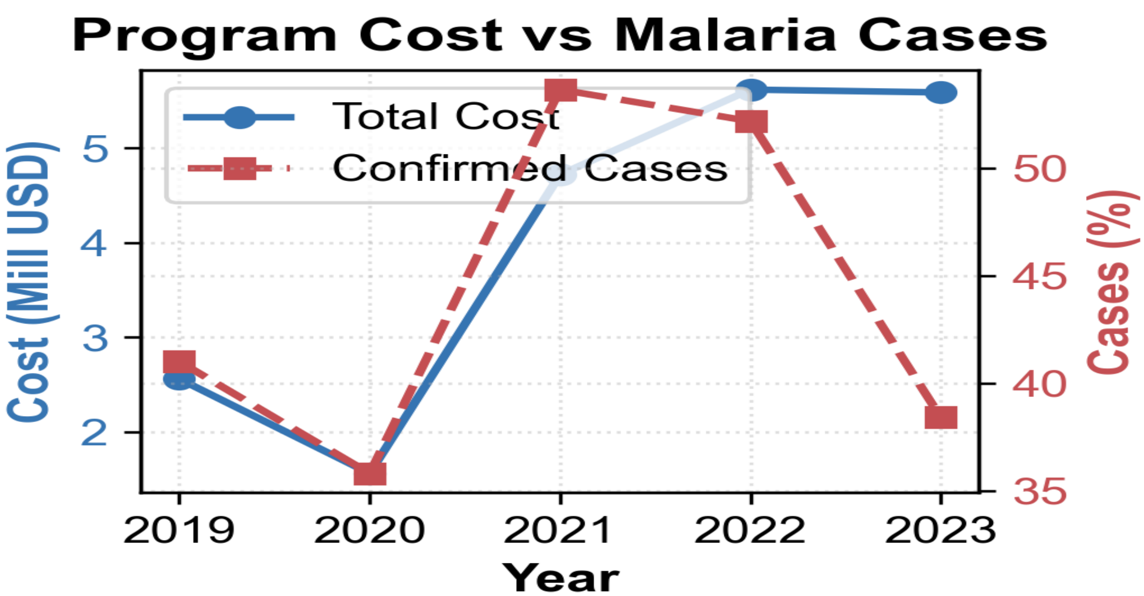

Figure 7: total malaria control program cost, and total confirmed malaria cases in Abobo district, Western, Ethiopia, 2019-2023.

5.4. Malaria program investment returns

Between 2019 and 2023, it demonstrated substantial and accelerating economic gains across key benefit categories. Productivity benefits showed the most dramatic growth, rising from $17.9 billion in 2019 **to** $17.4 billion in 2023, with notable peaks in 2021 and 2023. Insurance-related benefits increased steadily over the five years, more than doubling from approximately $1.0

million **to** $2.2 million. Employment-related benefits also expanded consistently, growing from $5.6 thousand **in** 2019 to more than $12.2 thousand by 2023.

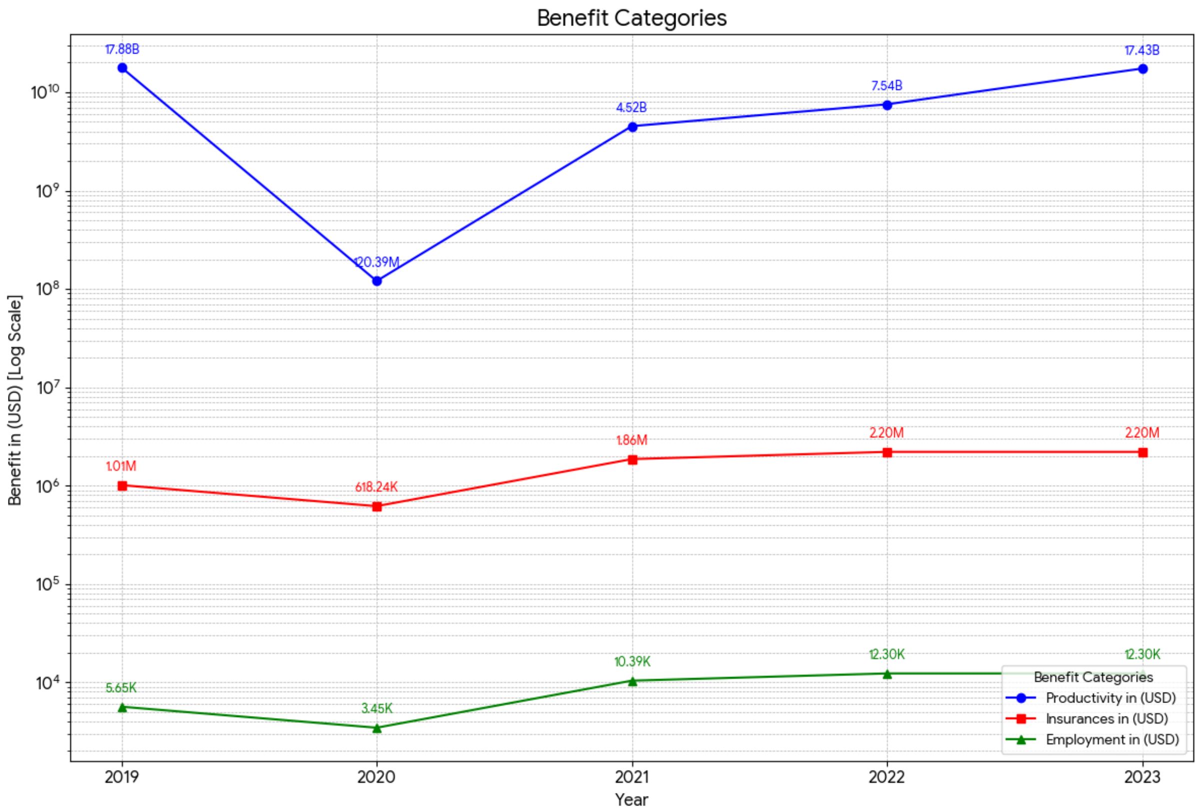

Figure 8: Estimated benefits of a malaria control program in USD across three categories in Abobo district, Western Ethiopia, 2019-2023.

Program costs ranged from USD 1.56 million to USD 5.62 million over the period, while benefits varied substantially, from USD 0.12 billion in 2020 to USD 17.9 billion in 2019 and USD 17.4 billion in 2023. Correspondingly, ROI values show very high economic returns.

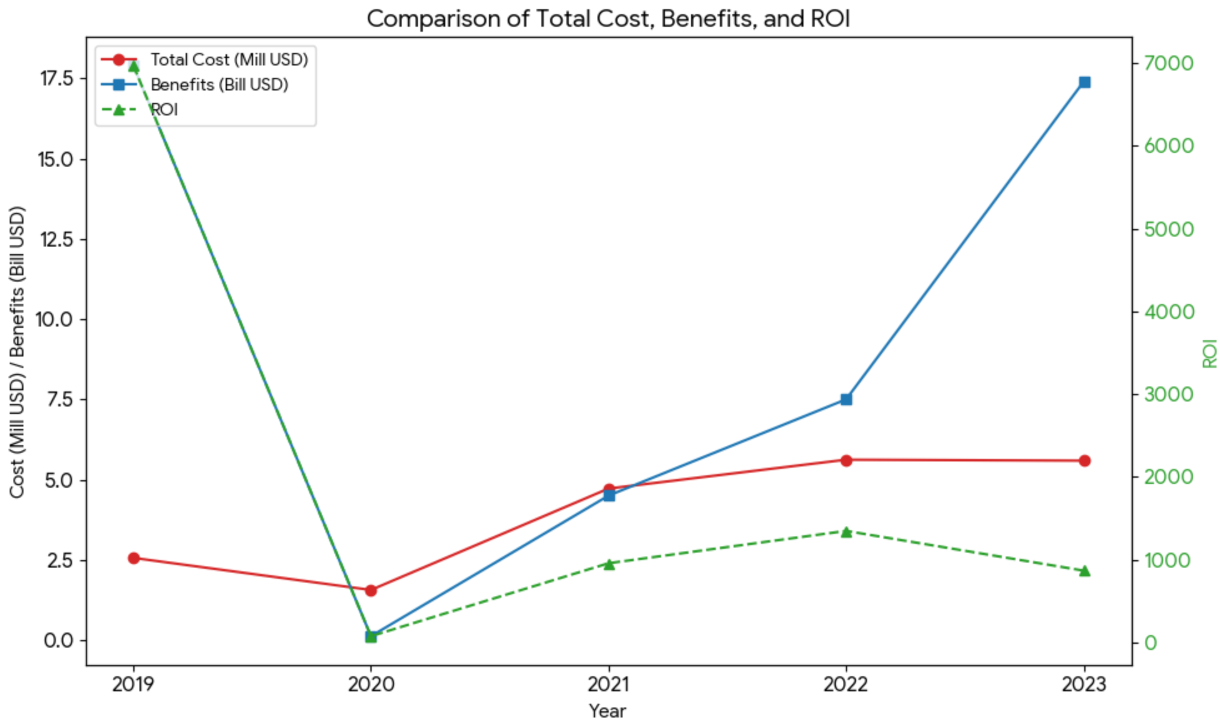

Figure 9: Trends of cost, benefit, and ROI of a malaria control program in Abobo district, Western, Ethiopia, 2019-2023.

5.5. Sensitivity analysis

When applying 26.6% inflation and 3% depreciation to all program cost components, total costs increased uniformly across all years, ranging from 26% to 27%. The largest increase was observed in 2022 (+1.52 million USD), followed by 2023 (+1.49 million USD) and 2021 (+1.26 million USD).

ROI decreased by approximately 21% in 2019–2022; however, a substantial decline of 71.7% was observed in 2023. Tornado diagrams constructed from the absolute changes demonstrated that 2023 had the highest sensitivity for ROI, while 2022 had the highest sensitivity for total cost. The analysis shows that although cost increases were predictable and proportional, ROI was highly sensitive to inflation in later program years.

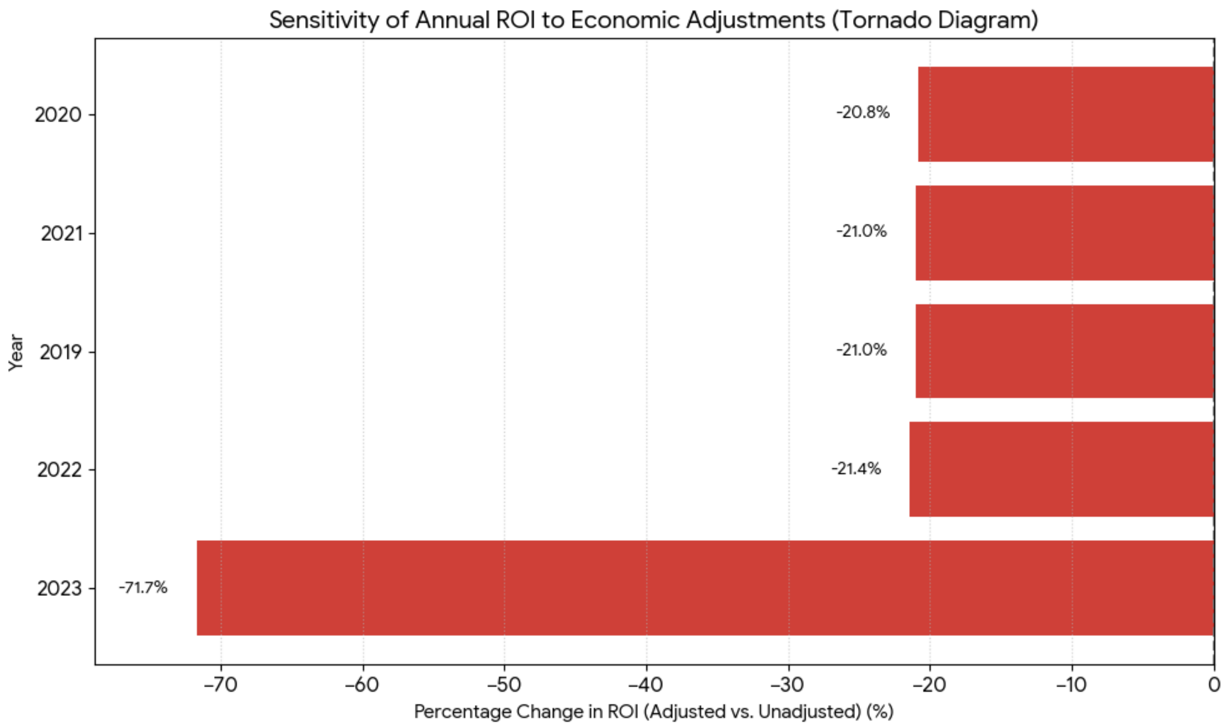

Figure 10: Sensitivity analysis of return on investment of malaria control program, Abobo district, Western, Ethiopia, 2019-2023.

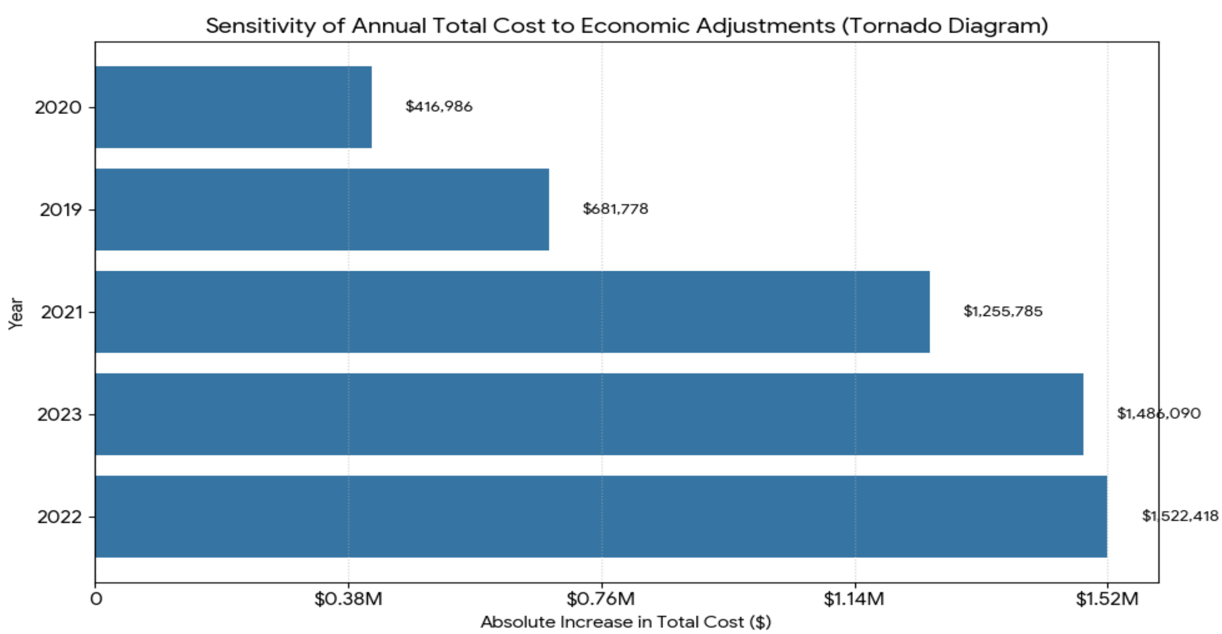

Figure 11: Sensitivity analysis of cost of malaria control program in Abobo district, Western Ethiopia2019-2023.

6. Discussion

Between 2019 and 2023, confirmed malaria cases showed an upward trajectory, with confirmed cases rising from 6,961 in 2020 to 28,056 in 2022 before dropping to 21,162 in 2023. This may be due to the global economic recession, with a subsequent decline in malaria investment through the aftermath of COVID-19 and other circumstances. According to the World Health Organization (WHO), many countries experienced disruptions in routine health services in 2020 due to COVID-19, which may have affected malaria case detection and reporting (World Health Organization, 2021). The overall pattern of malaria in the district may reflect changes in transmission dynamics, service uptake, intervention coverage, surveillance sensitivity, or service disruption. It aligns with findings from North Shewa, Ethiopia, where malaria incidence also showed significant year-to-year variation, with peaks observed in specific periods and a dramatic rise in *P. falciparum* cases between 2019 and 2021(55). In addition, a study conducted at Metehara Health Centre observed a steady decline in malaria prevalence from 2017/18 to 2021/22, followed by a significant increase to 26.5% in 2022/23 (56). Likewise, the overall pattern of malaria incidence in these studies showed pronounced year-to-year variability that could be influenced by environmental and other factors. In all these studies. The findings indicated that malaria severely hurts adults in the working age groups, highlighting notable vulnerability among the working-age population with implied socio-economic impact of the disease on the local community. Besides, the high proportion of Pf cases elucidates the risk of severe malaria cases, with great implications for the case management pillar of malaria control program. Though there was a high caseload during the entire year period, no death was reported, suggesting effective case management. Persistently high IRS coverage didn’t significantly reverse the overwhelming case number observed over the five years.

Abobo districts are part of the broader national efforts(57). Studies have shown that IRS coverage below 80% may not significantly impact malaria prevalence. A study in Wolaita Zone found that despite IRS application, the coverage was below the recommended 80%, leading to minimal reduction in malaria prevalence. The importance of achieving high coverage rates to effectively control malaria transmission (58). Additionally, integrating IRS into community-based health programs, such as Ethiopia's Health Extension Program (HEP), has proven effective. A study comparing community-based and district-based IRS models in Ethiopia found that the community-based approach led to increased coverage and efficiency. This model could be beneficial for

Abobo, potentially enhancing local engagement and sustainability of malaria control efforts (59). While districts have demonstrated consistent IRS coverage over the years, they have achieved and maintained coverage rates above 80%.

The cost of malaria case management was closely tied to case burden. It increased with the number of confirmed cases, a trend seen across multiple studies. Overall, the increase in case numbers led to a concomitant rise in cost, contributing for reportedly zero death in the district with supposedly better logistic management. However, the cost per case was $24, which is lower than elsewhere in the world, though Per-care costs can vary widely depending on the context and the perspective taken. A systematic review found that the median cost per malaria case treated was $9.31, but could rise as high as $89.93 for severe cases(60). In the Peruvian Amazon, the average cost per uncomplicated malaria episode was $161. Compared with $30.85 per case from the provider's perspective in Peru, the per-care cost reported in this study is slightly lower.

Vector control costs from this study range from $3.5 per person (2020) to $27.94(2023), significantly higher than the median research estimates of $1.1–$5.70 per person annually for vector control (60). This discrepancy may reflect differences in intervention types. Lower vector control spending was correlated with increased case number in 2020 and 2021, while increased expenditure on vector control was associated with decreased case number in 2023, highlighting the critical role of vector control interventions in suppressing transmission. The importance of sustained investment in the fight against malaria is noted in systematic reviews (60).

Between 2019 and 2023, the media education costs for malaria control programs in Abobo District ranged from $0.16 to $0.19 per person. These costs are consistent with those observed in other regions of the world implementing malaria control interventions, highlighting the feasibility and affordability of such strategies. For instance, a comprehensive school-based malaria program in Sikasso Region, Mali, estimated the total cost per child at $10.38, with media education accounting for approximately 20.5% of the total cost, translating to about $2.13 per child(61). Similarly, a community-level integrated prevention campaign in rural Kenya, which encompassed malaria education, was estimated to cost $31.98 per person (62). These findings suggest media education as a cost-efficient component in malaria control programs.

The constant RCCE budget of $956 throughout the entire period suggests consistent budget commitment on this pillar of malaria control program. While media and community engagement are essential components of malaria control programs, they may not have been sufficient to significantly reduce the number of malaria cases. Some studies suggest that sustained efforts in RCCE, combined with other malaria control measures like distribution of ITNs, indoor spraying, and early diagnosis and treatment, are necessary for notable reductions in malaria incidence (63).

Average cost of community engagement for malaria control in Abobo district is estimated at USD 0.03 per person, which is significantly lower compared to a study conducted in Myanmar, where the average cost was USD 2.85 per person (64). In districts like Abobo, where malaria transmission is intense, media campaigns alone may not suffice. A study by McCall found that media campaigns focusing on malaria prevention must be tailored to local contexts, using culturally appropriate messaging and involving community leaders to enhance trust and participation (65). To tackle the dynamic challenges of malaria transmission, strengthening program components, such as RCCE, is essential. Additional resources could allow for more targeted and expansive community-based interventions, which are effective in other settings (66).

The data in this study district indicate a consistent effort in malaria vector control through Indoor Residual Spraying (IRS) between 2019 and 2023. The number of structures sprayed varied from 4,888 in 2019 to 5,738 in 2023, reflecting a steady commitment to malaria control (67). The U.S. President's Malaria Initiative (PMI) Vector Link project, which operates in multiple regions of Ethiopia, reported spraying 487,746 structures in 2019 and 527,375 in 2020 across 44 districts, including Ababo, with an average of more than 11,000 structures per district.

District findings revealed a concerning trend: while malaria intervention costs had fluctuated, the number of confirmed malaria cases remained high. In 2019, the total intervention cost was $2,566,059, with 9,547 confirmed cases. By 2023, the cost had decreased to $5,590,225, yet the number of confirmed cases remained substantial at 21,162. This indicates that despite increased spending, the effectiveness of interventions may not have proportionally reduced the disease burden. Comparative studies highlighted the economic burden of malaria in Ethiopia. A study in Chewaka District found that households spent over 5% of their annual income on malaria-related expenses, with indirect costs, such as lost productivity, comprising the majority(68). Similarly, research in Adami Tulu District reported that the median cost of a malaria episode was $5.06, with indirect costs accounting for 61% (69). Nationally, Ethiopia allocates approximately 2.5% to 5.8% of its annual government budget to malaria control, with out-of-pocket payments constituting 6.4%

of total household health expenditures. Despite these investments, the persistent high number of malaria cases suggests challenges in the efficiency and targeting of interventions(70).

The Abobo District analysis reveals significant economic benefits resulting from malaria control interventions between 2019 and 2023. The multifaceted impact of an effective malaria control program. The substantial productivity benefits observed, particularly the $17.9 billion in 2019, highlight the critical role of malaria control in enhancing workforce efficiency and reducing malaria burden. However, it should be noted that attribution of productivity and insurance benefits exclusively to malaria interventions is difficult, as broader socioeconomic and health system factors may also contribute. Malaria-related absenteeism and reduced work capacity can significantly hinder economic output, especially in agriculture-dependent regions like Abobo. Studies have shown that malaria can lower GDP growth by up to 1.3% annually in affected countries. Therefore, the observed productivity gains suggest that malaria control efforts have effectively mitigated health and economic losses (71).

The employment benefits, though modest in monetary terms, reflect the broader impact of malaria control on labor force participation. The economic gain from a malaria program through increased employment and program spending was considerable, suggesting the resulting GDP impact of spending on malaria program. This aligns with findings from Uganda, where malaria eradication efforts led to a nearly 40% increase in the likelihood of male wage employment (72).

The insurance benefits, particularly the increase to $2.2 million in 2022, indicate a growing financial protection offered by local malaria control program by averting severe health crises like malaria epidemics. It shows that mitigated local economic fallout would be caused by malaria epidemic through mitigated economic risk, highlighting the value of local health workers' contribution to reducing epidemic economic risk. Yet, the declining ROI from 2019 to 2023 may reflect rising program costs relative to slower health gains, efficiency challenges, or diminishing marginal returns as transmission remains entrenched. These programs can also reduce out-of-pocket expenditures for households, thereby enhancing financial security. In Ethiopia, public financing of malaria interventions has been shown to eliminate substantial private health expenditures, with the poorest income quintiles experiencing the greatest financial risk protection(73). Comparative studies of the broader economic implications of malaria control. A study across 26 high malaria-burden countries estimated that scaling up malaria control could produce a dividend of $152 billion, equivalent to 0.17% of total GDP projected over the study period. Similarly, research in Kenya highlighted the economy-wide benefits of malaria control, including increased household labor endowment and reduced government health expenditure(74).

A systematic review of malaria control and elimination economics found that benefit-cost ratios (BCRs) ranged from 2.4 to over 145, indicating that investments in malaria control generally yield significant returns. Similarly, a study in Ethiopia comparing the cost-effectiveness of long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS) found that LLINs alone had an incremental cost-effectiveness ratio (ICER) of $207 per disability-adjusted life year (DALY) averted, suggesting cost-effectiveness compared to routine practice (75, 76). The data from districts illustrate the significant economic benefits of malaria control interventions. These benefits extend beyond health improvements to encompass enhanced productivity, increased employment, and better financial protection, thereby contributing to broader economic development goals. Our study allowed for multifaceted micro-level financial implications of malaria control program in Abobo district based on a standard model, providing a holistic view of the impact of malaria interventions. It showed the broader view of investment in malaria program. It provides insight into local malaria program investment focus and resulting disease trend for micro-scale targeted intervention planning and implementation.

7. Strength, and limitation of the studies

7.1. Strengths of the studies

- ✓ A comprehensive Cost-Benefit Analysis provides a thorough examination of both direct medical and non-medical costs associated with malaria interventions. This comprehensive approach allows for a more nuanced understanding of the financial implications of these interventions on the healthcare system and the community at large.
- ✓ Multifaceted Benefits Assessment of various benefits (productivity, insurance coverage, and employment) provides a holistic view of the impact of malaria interventions. It shows how health improvements can lead to broader economic benefits, which is essential for understanding the overall value of health investments.
- ✓ Contextual Relevance allows for an in-depth analysis tailored to specific local conditions, challenges, and opportunities. This localized approach can yield insights that are directly applicable to the community and inform targeted interventions.

7.2. Limitations of the studies

- ✓ The study may not fully account for external economic factors that influence productivity and employment outside malaria interventions. Like unemployment, rates or economic policies could affect outcomes independently of malaria control efforts.
- ✓ The study primarily focuses on short-term costs and benefits it does not overlook long-term impacts such as sustained improvements in health outcomes or persistent economic growth resulting from reduced malaria incidence.
- ✓ The studies not considering other health interventions or socio-economic programs implemented concurrently may confound the results, making it difficult to isolate the specific impact of malaria interventions on costs and benefits.

8. Recommendation

- ✓ Health Impact Assessment can help quantify changes in malaria incidence and prevalence, morbidity, and mortality rates before and after intervention implementation. By comparing health outcomes in populations receiving interventions with those that do not, researchers can assess the effectiveness of various strategies. This assessment should also consider co-morbidities and how malaria control can improve overall health in the community.
- ✓ Integration with Other Health Programs can maximize resource use and address multiple health challenges simultaneously. For instance, combining malaria education with maternal health services can lead to increased awareness among pregnant women about malaria prevention during pregnancy, improving both maternal and child health outcomes.
- ✓ Assessment of Indirect Economic Benefits helps to Understand how reduced malaria incidence contributes to increased workforce productivity, better educational outcomes, and enhanced community resilience

9. Conclusion

The data from the malaria intervention programs highlights both successes and challenges within malaria control efforts that underscore the complexities of healthcare financing. While direct costs exhibit substantial variability influenced by numerous factors, costs have steadily increased as public health initiatives gain traction benefits despite fluctuation caused by external factors. In addition, substantial investments have led to significant economic benefits, but ongoing challenges such as funding gaps, resistance issues, and climate change impacts threaten future progress. The economic benefits derived from reduced disease burden not only enhance community health but also contribute to broader socio-economic. Investment in vector control, capacity building, risk communication, and community engagements are essential for enhancing healthcare systems' resilience, to achieve sustainable health outcomes while managing costs effectively, Enhanced surveillance systems, improved healthcare infrastructure, and community education on preventive measures are critical steps toward effective malaria control in this endemic area. To sustain gains made against malaria, stakeholders must prioritize increased funding for interventions while also focusing on innovative solutions that enhance the effectiveness of existing strategies. Collaborative efforts among governments, international organizations, and local communities will be crucial for closing funding gaps and ensuring that resources are allocated efficiently. Policymakers must prioritize comprehensive strategies that address both immediate healthcare needs, and long-term public health goals. Future strategies should focus on optimizing resource allocation across various intervention categories to enhance efficiency while considering emerging challenges such as climate change impacts on vector behavior and migration patterns that could influence malaria transmission dynamics, and maximizing health outcomes for affected populations. Continued monitoring and evaluation will be essential in adapting these strategies to ensure that they remain both effective and economically viable as we strive for malaria elimination goals by 2030. Integrates various aspects of malaria intervention costs and benefits while emphasizing the need for continued investment and adaptation to emerging challenges within the field of global health. Related how the costs of malaria control interventions vary by year. What are the main factors driving the increase in costs. How effective are the interventions in reducing malaria cases and deaths .What are the productivity benefits associated with malaria control interventions how does the return on investment (ROI) change over the years.

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Annex I: Participant Information Sheet

My name is __________________. I am working as a data collector for the study conducted in Abobo by Dagim Tefera, who is studying for her Master's degree at Addis Ababa University, College of Health Science, and School of Public Health. I kindly request that you give me your attention to explain to you about the study and the study participants.

The study title: Assessment of cost and investment return including health gains of malaria control and elimination program in a malaria hot spot area, Abobo, District, Ethiopia

Purpose of the study: The main aim of this study is to write a thesis as a partial fulfillment of a Master's degree in public health for the principal investigator. After completion of this, study the results used as evidence and input to policy, and for the different strategies.

Procedure and duration: I will be assessing costs, investments on return, by using community health planning, and costing tools, which needs your cooperation, and it takes a few minute.

Risks and benefits: The Risk of participating in this study is nil since the study does not have the invasive procedure and does not require collecting any samples. There would be no any direct benefits for being a study participant but indirectly, the findings from this research will be important for improving by give evidence-based based information for policy makers, and for scientific knowledge.

Confidentiality: All information forwarded is kept confidential

Contact address: If you have any questions, which is not unclear, you can contact the investigator.

Investigator: Dagim Tefera

Mob +251-939168448 Email: - dagimtefera90@gmail.com

Advisor: Berhan Tassaw, 0911365200

Dr. Werissaw Hailselasiessi, 0904741367

Addis Ababa University, college of health sciences, school of public health

Annex II: informed consent form

Detailed information about the study was explained to me. I have understood that the objective of this study is to assess the cost and investment return, including health gains, of the malaria control and elimination program in Abobo.

In addition, I understand how the data collection is proceeding and the time it takes to complete the data collection. I also understand that the research imposes no risk on me. I assured that there would be confidentiality of my response, and the collected data would be used only for the study. It also explained to me that I have the right to stop participating at any time.

In addition, I understood that participating in this study is important for scientific knowledge and a basis for further study. Therefore, I have now consented to participate in the study by signing this form.

Signature of participants________________________ date _____________________

Name and signature of data collector_______________________ date _____________

Annex III (English version Questionnaire);

A tool for data collection for cost, investment on return, and health gains of Malaria control program in Abobo District, Ethiopia, a malaria hotspot area.

1. **Regional profile**

Region name--------------------

Name of person being interviewed---------------------------

Position title---

Years of service in current position--------------------------------------

Estimated monthly salary---

Gender---

Education--

Contact information------------------------------

Roles and responsibilities---------------------------------

Total population----------------------

Total number of referral hospitals------------------------------

Total number of general hospitals------------------------------

Total number of primary hospitals------------------------------

Total number of health centers-------------------------------------

Total number of health posts---

Total number of health professionals--

Attrition rate --

Accessibility/distance of health facilities in kms ----------------------------------

Partner's engagement/funding agent/ for malaria control program-----------------

Malaria incidence rate--

Malaria prevalence rate--

Malaria morbidity rate--

Malaria mortality rate ---

1. **<u>District profile</u>**

Total population-----------------------

Total number of under-five children -----------------------------

Total number of reproductive population -------------------------

Total number of female population -----------------

Total number of male population -------------

Total number of health centers---------------------------------------

Total number of health posts---

Total number of health professionals--

Attrition rate ---

Accessibility/distance of health facilities in km ------------------------------------

Partners engagement/funding agent/ for malaria control program-----------------

Malaria incidence rate--

Malaria prevalence rate--

Malaria morbidity rate--

Malaria mortality rate ---

Cost categories

Direct Medical cost (PF, PV, mixed)

Malaria testing cost -------------------------

Malarial drug cost -------------------------

Other drug cost -------------------------

Consultation fees--------------------------

Vector Control----------------

Capacity building -------------

Risk communication and community engagement (RCCE) ------------------

Direct non-medical cost

Transportation cost ------------------------

Food ---------------------------------------

Other Items (disinfectants), ---------------------------------

Overall cost

Total Direct Medical Cost ------------------

Total direct non-medical costs ------------------

1. **Cost at Health Center**

Health center name ---------------------

Name of person being interviewed----------------------------

Position title--

Years of service in current position--

Estimated monthly salary---

Gender--

Education---

Contact information-------------------------------

Roles and responsibilities-----------------------------------

Catchment population -------------------

Malaria Cases (RDT, Microscope, clinical)

Confirmed cases (PF, PV, mixed) ---------------------------------------

Probable cases (PF, PV, Mixed) ---

Suspected cases (PF, PV, mixed) --

Cost categories

Cost of malaria at health center (PF, PV, mixed)

Direct Medical cost

Malaria testing cost ------------------------

Malarial drug cost -------------------

Other drug cost ------------------------

Consultation fees-------------------------

Direct non-medical cost

Transportation cost -----------------------

Food --------------------------------------

Other Items --------------------------------

Overall cost

Total Direct Medical cost -----------------

Total direct non-medical costs -----------------

Main challenges--

--

2. Health Post

Health center name --------------------

Name of person being interviewed---------------------------

Position title--

Years of service in current position---------------------------------------

Estimated monthly salary---

Gender--

Education--

Contact information------------------------------

Roles and responsibilities---------------------------------

Catchment population ------------------

Malaria Cases (RDT, Microscope, clinical)

Confirmed cases (PF, PV, mixed) --------------------------------------

Probable cases (PF, PV, Mixed) --

Suspected cases (PF, PV, mixed) ---

Cost categories

Cost of malaria at health center (PF, PV, mixed)

Direct Medical cost

Malaria testing cost -------------------

Malarial drug cost -------------------------

Other drug cost ----------------------------

Consultation fees ----------------------------

Direct non-medical cost

Transportation cost -----------------------------

Food -------------------------------------

Other Items ------------------------------

Overall cost

Total Direct Medical cost ------------------

Total direct non-medical costs ------------------

Main challenges ---

<u>Benefits components</u>

<u>Productivity IN 2019</u>

GDP per capita ---

GDP per capita growth rate --

Life expectancies-------------------------------------

Productivity year gain --------------------------------------

Average benefit per death averted ------------------------------------

<u>Productivity IN 2020</u>

GDP per capita --

GDP per capita growth rate --

Life expectancies ------------------------------------

Productivity year gain -------------------------------------

Average benefit per death averted -----------------------------------

Productivity IN 2021

GDP per capita ---

GDP per capita growth rate --

Life expectancies ------------------------------------

Productivity year gain -------------------------------------

Average benefit per death averted -----------------------------------

Productivity IN 2022

GDP per capita ---

GDP per capita growth rate --

Life expectancies ------------------------------------

Productivity year gain -------------------------------------

Average benefit per death averted -----------------------------------

Productivity IN 2023

GDP per capita ---

GDP per capita growth rate --

Life expectancies ------------------------------------

Productivity year gain -------------------------------------

Average benefit per death averted -----------------------------------

Employment IN 2019

Total spending cost of program ---

Fiscal multiples ---

Employment IN 2020

Total spending cost of program ---

Fiscal multiples ---

Employment IN 2021

Total spending cost of program ---

Fiscal multiples ---

Employment IN 2022

Total spending cost of program ---

Fiscal multiples ---

Employment IN 2023

Total spending cost of program ---

Fiscal multiples ---

Insurances IN 2019

Economic impact of malaria--

Years over which malaria could occur ----------------------------

Annual economic risk from a severe health crisis -----------------------------------

Size of total health workforce ---

Number of health workforces (HWF) added during the interventions ---------------------

Annual values of (HWF) contribution to reduce in proportion to the size of total health workforce -----------------------------

Insurances IN 2020

Economic impact of malaria--

Years over which malaria could occur ----------------------------

Annual economic risk from a severe health crisis -----------------------------------

Size of total health workforce ---

Number of health work forces (HWF) added during the interventions ---------------------

Annual values of (HWF) contribution to reduce in proportion to the size of total health workforce ------------------------------

<u>Insurances IN 2021</u>

Economic impact of malaria--

Years over which malaria could occur ----------------------------

Annual economic risk from a severe health crisis -----------------------------------

Size of total health workforce ---

Number of health work forces (HWF) added during the interventions ---------------------

Annual values of (HWF) contribution to reduce in proportion to the size of total health workforce ------------------------------

<u>Insurances IN 2022</u>

Economic impact of malaria--

Years over which malaria could occur ----------------------------

Annual economic risk from a severe health crisis -----------------------------------

Size of total health workforce ---

Number of health workforces (HWF) added during the interventions ---------------------

Annual values of (HWF) contribution to reduce in proportion to the size of total health workforce ------------------------------

Insurances IN 2023

Economic impact of malaria---

Years over which malaria could occur -----------------------------

Annual economic risk from a severe health crisis ------------------------------------

Size of total health workforce --

Number of health workforces (HWF) added during the interventions ---------------------

Annual values of (HWF) contribution to reduce in proportion to the size of total health workforce ------------------------------

Annex IV ; principal investigators curriculum vitae

NAME DAGIM TEFERA

TEL; +251-939168448

E-MAIL; dagimtefera90@gmail.com

Education background;

11. 2023-uptodate; MPH with specialty in Health Economics
12. 2022-2023; Assistant Lecturer in Arba-Minch Health Science college
13. 2017-2021; BSC in Public Health from Arba-Minch University
14. 2015-2016; Preparatory school in Arab-Minch secondary and preparatory school
15. 2013-2014 ; Secondary school in Abaya Secondary school
16. 2005-2012; Primary school in Sekila Primary School

Professional Experience

Assistance Lecture

Duties and Responsibilities

- ✓ Teaching the students like health Education, basic Biostatics……………….
- ✓ Coaching the student in different conditions on school stays, and in filed works.
- ✓ Participating on different research symposium, seminary
- ✓ Perform other duties assigned by college

Language proficiency

	Speaking	Writing	Listening	Reading
Amharic	Excellent	Excellent	Excellent	Excellent
English	Excellent	Excellent	Excellent	Excellent

Trainings

- Certified in the SPSS SOFTWARE from the Addis Ababa university school of commerce
- Certified in the KOBO DATA COLLECT SOFTWARE from Arba Minch College of Health Sciences.
- Certified in the Open Data Kit (ODK), SOFTWARE from Arba Minch College of health sciences
- Verified Certificate of Nano degree Program Completion: Data Analysis Fundamentals.

COMPUTER SKILL

General knowledge of computers, including -

- **application software**
  - ✓ Excel
  - ✓ Microsoft word
  - ✓ PPT preparation
  - ✓ SPSS software
  - ✓ KOBO DATA COLLECT SOFTWARE
  - ✓ ODK DATA COLLECT SOFTWARE

INTERESTS (HOBBIES)

- ✓ Reading books, writing, communicating with others, walking, Teaching, Cooperative works.
- ✓ Helping others as much as possible.
- ✓ Love of work.

REFFERENCE

- ✓ Inst. Desta Haftom (Assistant professor of public health) at Arba Minch university, +251948244192, E-mail destish.haf@gmail.com/desta.haftu@amu.edu.et
- ✓ Inst, Firdawek Getahun (Assistant professor of public health) at Arba Minch university, +251927233345, E-mail. getahunfirdawek@ymail.com
- ✓ Inst, Abayneh Tunje (PhD fellow@ Lund university, Sweden, Assistant professor of public health) +251920011972, E-mail;

abaynehtun@yahoo.com/abayneh.tunje@amu.edu.et abayneh-tunje.tanga@med.lu.se/

Declaration

I, the undersigned, declare that this is my original work, has not been presented for a degree in this or other university, and that all sources of materials used for this thesis have been fully acknowledged.

Name: Dagim Tefera

Signature ____________________

Place: Addis Ababa University

Date of submission

This thesis has been submitted for examination with my approval as university advisor.

Name:	Signature
Berhan Tassew (MPH, Assistant Professor)	____________________
Werissaw Haileselassie (MPH, PhD, Assistant Professor)	_________________