Estimating the Cost of the integrated Measles-Rubella Campaign in Sierra Leone

Final report

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BREAKING NEW GROUND

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EXECUTIVE SUMMARY

Background

In June 2019, Sierra Leone conducted a seven-day integrated campaign, delivering measles-rubella (MR) and oral polio vaccines (OPV) nationwide, and vitamin A supplements and deworming tablets (albendazole) in half of the country's districts. Interventions were delivered at health facilities, temporary fixed sites such as schools and community centres and by mobile teams in the community. Mop-up activities were also conducted after the campaign to immunize those who had not been reached during the campaign. The administrative coverage of the campaign was 99% for MR vaccination, 120% for OPV, and 97% for each of the nutritional interventions. This campaign was financed by Gavi, the Vaccine Alliance and the government of Sierra Leone, and supported by the World Health Organization (WHO), United Nations International Children's Fund (UNICEF), and other partners. The cost of delivering immunization through campaigns is not well understood, and to our knowledge, evidence on the cost of integrated campaigns is non-existent. This study is the first comprehensive estimation of immunization campaign delivery costs in Sierra Leone.

Methodology

Costs were estimated from the payer perspective, including costs incurred by health service providers, the Ministry of Health and Sanitation, and development partners, using a mixed methods approach, combining financial expenditures and ingredients-based costing. The sample included three districts that delivered only MR and OPV (Koinadugu, Pujehun and Tonkolili) and three districts that delivered vaccines as well as nutrition supplements during the campaign (Bonthe, Bombali and Port Loko). Bonthe (riverain) and Koinadugu (hilly) were purposively selected in agreement with the Expanded Program on Immunization (EPI) team, while the other four were selected randomly. Within the districts, 30 facilities were randomly selected to include a mix of facility types and urban and rural facilities. Data were collected retrospectively between October 2019 and February 2020 from the selected facilities, district health offices, and the national government, as well as from district and national level partners. Costs were categorized by activity (e.g., training, service delivery, social mobilization, etc.) and resource type (e.g., per diems, transport costs and volunteer labor, etc.). Costs were aggregated to estimate the volume and sampling probability weighted average of the financial and economic cost per dose delivered, as well as the total cost of the campaign.

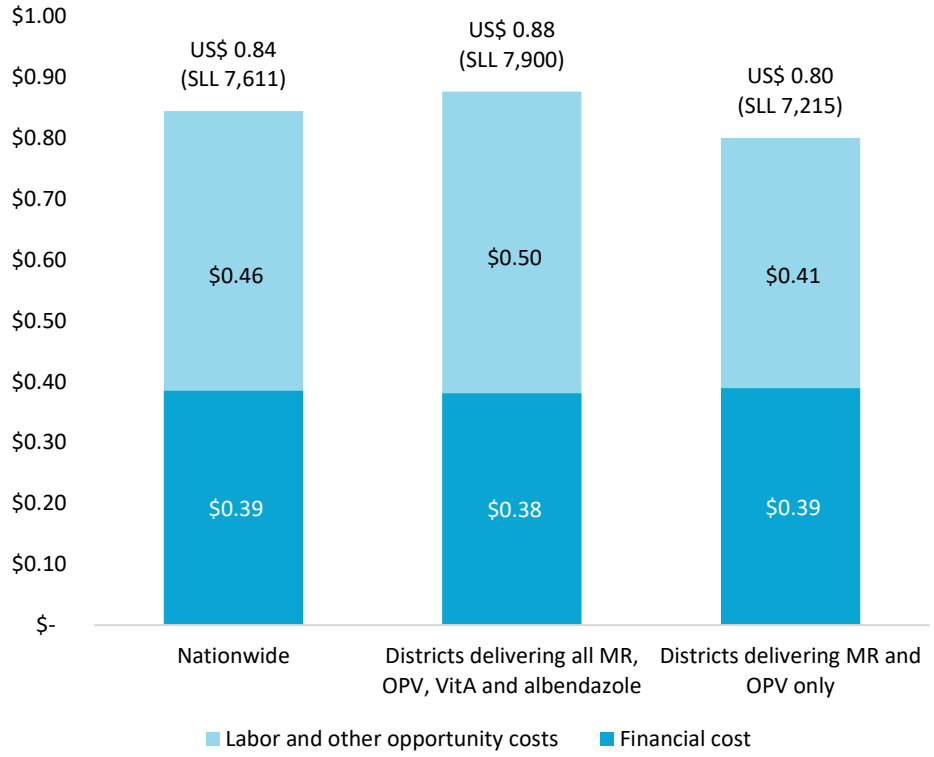
Key findings

The total financial cost of the campaign was US$ 3,943,200 (SLL 35,529,101,566), and the delivery cost (excluding the cost of vaccines and nutrition supplements) was estimated at US$1,566,596 (SLL 14,115,375,656). Service delivery was the main component of both the financial and economic delivery cost of the campaign, followed by training and social mobilization. Per dose delivered, the financial delivery cost was US$ 0.31, mainly driven by per diems and travel allowances. The opportunity cost of delivery was estimated at US$ 0.38 per dose delivered, of which 94% consisted of the value of paid and unpaid labor, and only a small share of capital costs. The total economic delivery cost (summing the financial and opportunity costs) was thus US$ 0.69 per dose. The majority of the delivery costs were incurred at facility level, even if they may have been paid for at other levels.

The financial delivery cost per vaccine dose (MR and OPV) was similar in districts which delivered MR and OPV only compared to those which delivered MR, OPV, Vitamin A supplements and deworming tablets (US$0.39 and US$0.38 respectively). This is an indication that financial cost efficiencies could be achieved through campaign integration. However, the opportunity costs (mainly the value of labor) were higher in districts that delivered the additional interventions, which demonstrates the importance of the use of existing routine resources to deliver integrated campaigns. Based on survey data, it appears that districts which delivered

additional nutrition interventions achieved similar MR coverage compared to those which only delivered vaccines.

The economic delivery cost per MR and OPV dose administered: nationwide and in districts delivering all interventions versus MR and OPV only (2019 US$)



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ACRONYMS

AEFI	Adverse event following immunization
BMGF	Bill & Melinda Gates Foundation
CHC	Community health centre
CHP	Community health post
cMYP	Comprehensive multi-year strategic plan
DHMT	District Health Management Team
EPI	Expanded Program on Immunization
HMIS	Health management information system
ICAN	Immunization Costing Action Network
IEC	Information, education and communication
IRC	International Rescue Committee
LCU	Local currency unit
LMICs	Low- and middle-income countries
MCH	Maternal and child health
MCHP	Maternal and child health post
MCV	Measles-containing vaccine
MOHS	Ministry of Health and Sanitation
MR	Measles-rubella
MSF	Médecins Sans Frontières
NGO	Non-governmental organization
OPV	Oral polio vaccine
SECHN	State enrolled community health nurse
SIA	Supplemental immunization activity
SLESRC	Sierra Leone Ethics and Scientific Review Committee
SLL	Sierra Leone Leone
SSL	Statistics Sierra Leone
USD	United States dollars
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

1. INTRODUCTION

With its first dose and second dose coverage levels at 93%[1] and 72%,[2] respectively, Sierra Leone is expected to require several more measles campaigns in the coming years to achieve measles elimination. Measles elimination requires countries to achieve two-dose routine measles vaccination coverage of at least 95%.[3] In June 2019, Sierra Leone held a seven-day nationwide measles-rubella (MR) campaign, which targeted all children aged 9 months to 14 years old for MR through facilities, temporary fixed sites and mobile outreach. Following the campaign, both doses in the routine program were replaced by MR.[4] The campaign was integrated with the delivery of oral polio vaccine (OPV), as well as vitamin A supplementation and albendazole tablets in half of the country's districts, using the same delivery vaccination teams and delivery modalities.

This study is the first costing study to estimate the financial and economic costs of a health campaign that co-delivered four interventions and the first to cost an immunization campaign in Sierra Leone. Despite their resource-intensive nature, little evidence exists on the cost of campaigns. Out of over 660 unit costs compiled in the Immunization Delivery Cost Catalogue (IDCC), only 33 are for campaigns and outbreak responses, and none are for Sierra Leone.[5] This study retrospectively estimated the full financial and economic cost of the integrated campaign, analyzed cost differences between geographic settings, interventions and delivery strategies, and identified key cost drivers. The results can help Sierra Leone and other countries improve planning and budgeting for future campaigns.

2. BACKGROUND

As in many countries, the cost of conducting a campaign in Sierra Leone is not well understood. Out of over 660 unit costs compiled in the Immunization Delivery Cost Catalogue (IDCC), none contained primary costing data from Sierra Leone.[5] At the time of its application for Gavi support in 2017, the operational cost of the measles-rubella (MR) campaign in 2019 in Sierra Leone was estimated at US$2,344,068 (of which the government had committed to fund 11%), amounting to US$0.76 per child targeted. This commitment is slightly lower than Gavi's assumption of US$0.80 per child. Gavi's operational support for campaigns is US$0.65 per targeted child, which it estimates covers 80% of an average campaign's costs. However, this is an average based on a wide range of data for many LMICs and different types of campaigns, using decades-old Comprehensive Multi-Year Plan (cMYP) estimates[6]. The Measles & Rubella Initiative calculates that the cost of a measles or MR campaign is US$1.00 per child vaccinated, which could be higher or lower than Gavi's estimate, depending on the coverage reached.[7] Therefore, it was not clear whether the MR campaign in Sierra Leone was adequately funded or not.

As the costs of immunization in Sierra Leone are expected to increase over the coming years, including the amounts that the government will have to cover, it is critical to generate evidence on the cost of delivering immunization, to aid accurate financial planning. In 2019, US$10.4 million was spent on routine immunization, of which the government funded US$3.2 million (31%), almost double the amount of 2015.[8] The total resource requirement for routine immunization was projected to rise to US$15 million in 2021, with an additional US$5.8 million for supplemental immunization activities.[9] With its first dose measles-containing vaccine (MCV) coverage at 93%[1] and MCV second dose coverage at 72%[2] in 2019, Sierra Leone is expected to require more MCV campaigns to increase coverage. In order to better prepare for future immunization campaigns, it is crucial for the country to have a better understanding of how much it actually costs to conduct an immunization campaign.

In June 2019, a seven-day national integrated MR campaign was held in Sierra Leone. MR and polio (OPV) vaccines were distributed nationwide and were co-delivered with vitamin A supplementation and albendazole deworming tablets in selected districts. The MR campaign conducted in June 2019 was the first

time two antigens were administered in the same campaign in Sierra Leone, with MR vaccines and OPV being delivered nationwide. Vitamin A supplements and deworming tablets were also administered in half of the country's districts. Several strategies were implemented to deliver the interventions. The fixed post (facility-based) strategy utilized included all functional health facilities (1,284), including hospitals and some non-profit and for-profit private facilities that had a memorandum of understanding (MOU) with the districts. Temporary fixed sites were set up at schools, business centers, transit points, markets and other locations as identified by the local community and health teams. Mobile teams moved from community to community and to reach populations that did not have access to a fixed site but were too small to justify an all-day fixed post or were unlikely to visit the nearest fixed site. Following the seven days of the campaign, most facilities conducted mop-up activities to reach children who were not vaccinated during the campaign. Table 1 gives an overview of the interventions delivered, the age groups targeted and the number of doses delivered. The administrative data gave a 98.6% coverage rate for MR nationwide, while the post-campaign coverage survey found a coverage level of 93.2% based on vaccination card or recall.[10] The administrative coverage levels reported sometimes exceeded 100%, due to denominator issues.

Table 1: The target age groups and doses delivered per intervention

Intervention	Target age group	Administrative data target cohort size	Administrative data number of doses delivered
Measles-rubella vaccine	9 months – 14 years	3,033,444	2,991,405
Polio vaccine	0 – 59 months	1,064,507	1,254,135
Vitamin A	6 – 59 months	452,220	440,229
Albendazole	12 – 59 months	372,181	375,130

3. STUDY DESIGN, SCOPE AND METHODS

3.1 STUDY AIMS AND OBJECTIVES

The purpose of the study was to retrospectively estimate the full cost of the implementation of the integrated campaign in Sierra Leone. More specifically, the objectives of the study were:

- To estimate the full financial and economic cost of the integrated campaign;
- To identify the main cost drivers of the integrated campaign;
- To determine how the cost and cost drivers vary by delivery strategy, geographic area and other factors to facilitate future budgeting and planning;
- To compare the financial delivery cost of the campaign against global estimates;
- To estimate the implications of co-delivery on the cost of implementing a campaign.

3.2 STUDY DESIGN

This was a retrospective study that captured the full financial and economic costs of the campaign. The study estimated both the operational cost of the campaign as well as the cost of the commodities. Operational costs are defined as the costs associated with delivering immunizations to target populations, exclusive of vaccine costs, but including supplies.[11] The costs included in the study captured both the additional resources used to implement the campaign (such as per diems and supplies), as well as an estimation of the use of existing resources (such as capital costs and a share of routine government health worker salaries). Costs were collected from all administrative levels in Sierra Leone that participated in the implementation of the campaign (national, district, and facility level) and all costs incurred from the moment the planning activities for the campaign first started until the final reports were submitted (generally from about six months before and up to one month after the campaign).

The study was conducted from the payer perspective, including costs incurred by health service providers, the Ministry of Health and Sanitation, and development partners. The study captured the costs of all health sector stakeholders that supported the implementation of the campaign, including the Ministry of Health and Sanitation (MoHS) and the technical partners supporting the campaign at national level (i.e., WHO and UNICEF), as well as partners that provided support at district level (CARE, Concern/Saving Lives, Doctors with Africa CAUMM, International Rescue Committee (IRC), Médecins Sans Frontières (MSF), Restless Development, Save the Children, and World Hope). Costs incurred by other sectors and government entities, and the beneficiaries were not included, as they were expected to be small. These could have included costs for the District Deputy Directors of Education and schools to organize the campaign, as well as the costs to households of traveling to immunization sites. As much as possible, the study team tried to capture a breakdown of the sources of funding. The study received ethical approval from the Sierra Leone Ethics and Scientific Review Committee (SLESRC), and steps were taken to ensure that the names of the participating health facilities remained confidential.

3.2 METHODOLOGY

The costing study used a mixed methods approach, combining financial expenditures and bottom-up micro-costing (or ingredients-based). Campaign-related activities at each administrative level (defined in Table 2) were costed by measuring the quantity of the inputs (resource types are defined in Table 3) used to achieve these activities, which were then multiplied by a price for each of these inputs (unit cost) to calculate the cost of each resource type under each activity. Most data used in this study was collected through in-person interviews at national level, district health offices and facilities, and through email from technical and implementing partners at national and district level. Campaign-related records which were reviewed included budgets, distribution matrices, expenditure records, micro-plans, reports, and tally sheets. Salary scale information was provided by the Expanded Programme on Immunization (EPI) staff. Online articles and reports were utilized to provide unit costs for fuel[12] and building space[13], and data points on fuel consumption.[14,15] UNICEF provided estimated replacement prices and useful life measurements for the vehicles and equipment used during the campaign. Costs were mostly collected in Sierra Leonean leones (SLL) and converted to US dollars (US$) using the World Bank Official exchange rate (Local currency unit (LCU) per US$, period average 2019) at 9010 SLL to 1 US$. Out of pocket expenditures by staff members (e.g., airtime) were considered additive and not assumed to be covered by per diems or allowances received.

Table 2: Definition of campaign activities

Campaign activity	Definition
Campaign management	Time and resources spent on planning, budgeting, managing the immunization program at various levels, including attendance at immunization-related meetings. General management of the health system has not been allocated here.
Vaccine, Vitamin A and albendazole collection, distribution and storage	Time and resources spent collecting vaccines and other campaign commodities at the airport or other distribution points, storing vaccines in national or subnational cold stores, distributing vaccines down to the facilities, and to the temporary campaign sites.
Cold chain maintenance	Time and resources spent on cold chain maintenance at all levels.
Training	Time and resources spent attending and/or providing campaign-related training. All trainings held in the lead up to the campaign have been considered fully campaign-specific. Training costs include the cost of venue, per diem for participants, cost of trainers, and reproduction of training materials.
Social mobilization and advocacy	Time and resources spent on mobilizing the community and households, and advocating for vaccination. This includes the costs of holding community meetings, printing flyers and educational materials, conducting events, and the cost of television and radio time etc.
Supervision	Time and resources spent on supervising subordinate or peer health or community workers, including staff time and transport costs etc.
Service delivery: facility-based	Time and resources spent on the act of administering the vaccine or delivering vitamin A and albendazole to children within the facility/compound.
Service delivery: temporary fixed sites	Time and resources spent on traveling to and from temporary fixed sites and the act of administering the vaccine or delivering vitamin A and albendazole to children at these sites. Temporary fixed sites could include schools, market places, and churches.
Service delivery: mobile teams/outreach	Time and resources spent traveling to and from mobile sites and the act of administering the vaccine or delivering vitamin A and albendazole at these sites.
Service delivery: sweeping/mop-up	Time and resources spent on traveling to and from sites and the act of administering the vaccine or delivering vitamin A and albendazole to children not reached during the campaign.
Waste management	Time and resources spent on disposing sharps and infectious non-sharp waste.
AEFI management	Time and resources spent following-up on adverse events following immunization (AEFI).

Record-keeping, HMIS, monitoring and evaluation	Time and resources spent on health management information systems (HMIS), data entry and analysis, including maintaining stock registers and records of children vaccinated, completing reports and analyzing, monitoring, and evaluating campaign data.

Table 3: Definition of resource types and calculations

Resource type	Description
Operating costs	
Paid labor	Allocation of salaried labor to campaign-related activities. Salaries are fully loaded thus including any regular fringe benefits. Includes regular monthly stipends paid to volunteer workers.
Volunteer labor	Estimation of the market value of volunteer labor used for campaign-related activities. For unpaid health workers, an equivalent salary grade was collected.
Workshops and meetings	Costs related to workshops, trainings and meetings, including the venue and refreshments provided on the day, but not including transport or per diem costs.
Per diem and travel allowances	Any allowances paid to campaign staff and health workers for campaign-related activities.
Transport and fuel	Cost of bus fares, boat travel/hire, vehicle hire, and the cost of fuel for campaign-related transport.
Vaccines, vitamin A and albendazole	Cost of vaccines, vitamin A and albendazole, including wastage and, freight and insurance fees.
Vaccine injection and safety supplies	Cost of auto-disabled syringes, reconstituting syringes, safety boxes and other supplies used for the administration of vaccines or delivering vitamin A and albendazole during the campaign.
Stationery and other supplies	Cost of stationery and other supplies used for the campaign.
IEC and other printing costs	The cost of printing immunization cards, training materials, radio jingles, tv ads and other information, education, and communication (IEC) materials that are campaign-related.

Communication	Costs related to purchasing airtime and mobile data for the purpose of the campaign, as well as a portion of regular phone and internet connection charges.
Incinerators (operating cost)	The cost of running incinerators used for the campaign.
Vehicle maintenance	Cost of maintaining vehicles (of all types) used for campaign-related activities.
Utilities	Costs related to building overheads, including maintenance, and utilities with a portion of these costs allocated to the campaign.
Cold chain repairs and energy costs	The cost of repairing existing cold chain equipment and running the cold chain (electricity etc.).
Capital costs	
Buildings	Value of the building space used to deliver and store vaccines.
Cold chain equipment	Value of all cold chain equipment used to store and transport vaccines.
Vehicles	Value of all vehicles and modes of transport used for the campaign.
Incinerators (capital cost)	Equipment used for incinerating waste at all levels.
Other equipment	Value of other equipment, such as generators, computers, printers, peripherals, phones, other medical equipment used for campaign-related activities.

Capital costs were annualized and discounted, and allocated to the campaign using the number of vaccination days as a share of the useful life of the equipment. A straight line depreciation of capital items was included using the number of campaign days as a share of the estimated useful life of the vehicle or equipment item. If the useful life estimate provided by UNICEF was less than the indicated age of the items as provided by the facility or DHMT, the age of the item was used as its useful life instead. Capital costs were discounted at a rate of 3%. The economic costs also include an estimate of volunteer time, which was valued as an equivalent of the salary grade or assumed to be in line with the average casual labor wage in the corresponding district.

In order to allocate costs that were shared between the campaign and the routine system, or between activities, resource types and interventions, allocation rules were established. Most of the resources were allocated based on time spent (labor, buildings, equipment, utilities, and vehicles). Cold chain costs were allocated based on the share of the campaign's commodity volume, and incinerator usage for incinerator costs. Due to the integrated nature of the campaign, many costs could not be traced back to a single

intervention (MR, OPV, vitamin A and albendazole administration). The proportion of the doses delivered was used to allocate shared costs to the different interventions. Cold chain related costs and AEFI management were allocated between MR and OPV only. Waste management costs, vaccine injection and safety supplies, incinerators (capital) and incinerators (operating) resource types costs to MR only. Detailed cost calculation methods and allocation rules are described in Annex II. Vaccine and commodity unit costs from UNICEF price lists and the supply division catalogue were used.[16,17,18,19]

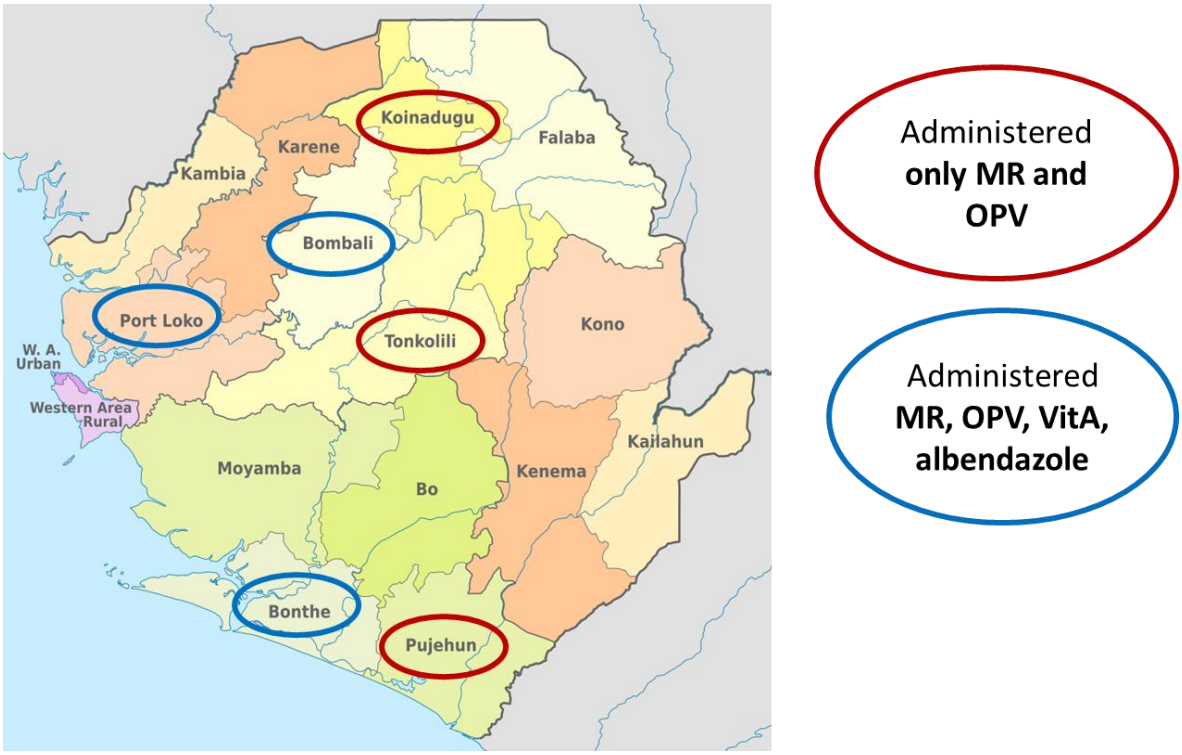
3.3 SAMPLING STRATEGY

Six out of the country's 14 districts were included in the sample. Two districts were purposively selected by the EPI team as their hilly and riverain geographic characteristics were assumed specifically challenging during the campaign, and the four other districts were selected randomly. Figure 1 shows the location of the sampled districts in Sierra Leone. To reflect that half of the districts administered all four interventions during the campaign, half of the sample's districts administered all four, while the other half administered only MR and OPV. Stratified random sampling was used to select the health facilities within the districts to include a mix of urban and rural facilities, and a mix of different facility types (see Table 4). 'Non-public' facilities were either private for-profit, faith-based or NGO-operated clinics or hospitals. The Sample Design Optimizer[20] was utilized to explore efficient sampling designs that minimized the relative error and data collection cost. As not every district had facilities of all the types specified in the table, our final selection included 30 facilities (as opposed to 42 that the sample design would allow for).

Table 4: Sample design parameters

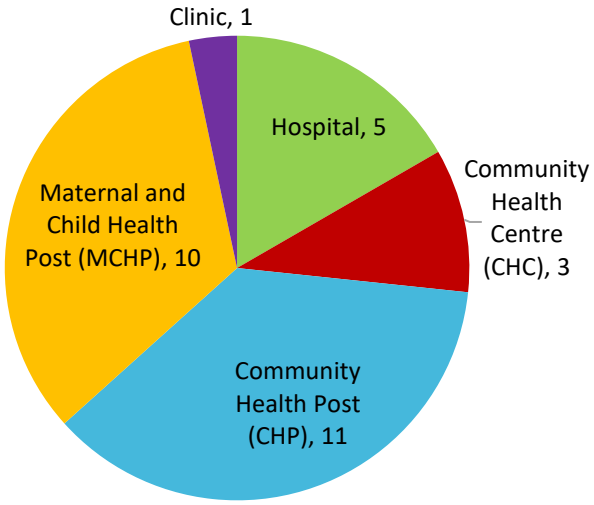
District	Facilities	Campaign sites
- 3 districts administering MR, OPV, vitamin A and albendazole - 3 districts that administered only MR and OPV - Of which 1 hilly district (Koinadugu) and 1 riverain district (Bonthe)	In each district, select: - 2 public rural facilities - 1 non-public rural facility - 1 rural hospital - 1 urban hospital - 1 urban non-public hospital - 1 urban public facility	Cover all campaign sites and teams that were under the management of the selected facilities

Figure 1: Map of Sierra Leone and sampled districts



Most facilities in the sample (two thirds) were located in rural chiefdoms. Upon arrival at the facilities, four of the nine facilities that in the sampling frame were indicated as private, faith-based or NGO facilities, turned out to be public facilities. The selected facilities were small, with many serving a catchment population area of fewer than 5,000 people (37%) or between 5,000-10,000 people (33%), and only 20% served between 10,000 and 30,000 people. Only the three district hospitals served a much larger population, including over 200,000 inhabitants. These hospitals also indicated that they do not normally provide routine immunization services, while most other facilities (60%) indicated that they offered routine immunization services twice per week. Figure 2 shows the breakdown of sampled health facilities by type.

Figure 2: Sampled health facilities by type (n=30)



3.4 DATA COLLECTION

The data at facility and district level was collected from October 2019 until February 2020 by a team of four data collectors and one supervisor, using laptops and tablets. The data collection team underwent one week of training and participated in two days of pilot testing of the study materials at the district health office and two facilities in the Western Rural district. Materials were subsequently revised to reflect learnings and feedback. Data collectors worked in teams of two, and the supervisor alternated in joining the two teams to ensure quality and consistency across the data collection teams. Twelve facilities were visited once by data collectors while the other 16 were visited twice. All district health offices were visited at least twice except for Pujehun district health office which was visited once.

The data collection questionnaires were designed for use in Excel, on tablets or on paper, and the Excel-based version was used most frequently. Questionnaires for district and facility level use were designed in Excel as well as on the Ona platform in order to collect data using tablets. The questionnaires in both Excel and Ona format contained built-in validation checks to aid data collectors. The Excel version of the questionnaire was deployed in almost all instances due to data collector preference, and laptops were used to record responses directly into Excel rather than using the questionnaires in a paper-based format. In the few instances where the tablet-based Ona questionnaire was deployed, issues with the pages crashing and data not uploading were encountered.

Where questionnaire data was missing or unavailable, alternative sources and assumptions were necessary. Completed facility and district sheets were sent to the ThinkWell team for review and went through several rounds of revision. Stock records for the vaccines, supplements and injection supplies were the most common missing data at facilities. When stock records were incomplete, district level microplans or distribution matrices were used to determine the number of vaccines and supplies distributed to the facilities. Or if the data on the number of vaccination supplies were also not available at district level, then the number of supplies such as syringes were calculated based on the number of doses delivered plus 5% wastage.[21] However, weak stock records at many facilities meant that estimating wastage remained challenging. From the distribution matrices at district level, it would not be possible to know how many vaccines had been wasted, or whether leftover vaccines had simply been used up as part of the routine program. The breakdown of doses by delivery strategy, particularly the number of doses delivered during the mop-up, was also frequently missing. Estimates of the proportion of doses delivered during the mop-up from other facilities were applied, and when no information on the strategy breakdown was available, the length of time spent on each strategy during the campaign was used to allocate doses. The age and replacement price of equipment items was also generally not available at facility level, mostly because items had been procured at national level, and estimates of the prices and useful lives were provided by UNICEF.

Data was collected from national level government and partners at both district and national level using a combination of email correspondence and in-person interviews. Due to constraints related to the COVID-19 pandemic, the initial full national level questionnaire was considered too burdensome, and a reduced list of questions to capture key cost components and expenditure reports were used. Aside from the EPI team, the Nutrition team, WHO and UNICEF, 20 organizations were contacted with requests for information, and data was received from 10, of which nine could be included in the analysis. A full list of the national and district level partners which contributed to this study can be found in Annex I.

3.5 DATA ANALYSIS

To calculate the average unit costs at facility and district level, we used a volume weighted average, also accounting for sampling probability.[22] Total costs for each of the sites and the unit cost calculations were carried out in Microsoft Excel. Costs were calculated for each cost type (financial/opportunity cost and campaign-specific/shared cost), intervention (MR, OPV, Vitamin A, Albendazole), delivery strategy (facility-based, fixed sites, mobile, mop up), cost activity (see Table 2), resource type (Table 3), and funding source (MOH, donors, facility). The sum of the total costs from all sites (weighted by the inverse probability of sampling) was divided by the sum of the delivery volume across all sites (weighted by the inverse probability of sampling) to estimate unit costs. This is shown in (*a*), where *n* is the number of facilities/districts in the sample, *Ci* represents the total service delivery cost at facility/district *i*, Qi represents the total service delivery volume at facility/district *i*, and *wi* is the inverse probability of sampling for facility/district *i*. This was calculated at both facility level and district level.

$$a)\ unitcost_{svw} = \frac{\sum_{i=1}^{n} C_i * w_i}{\sum_{i=1}^{n} Q_i * w_i}$$

Variance in the unit costs is calculated is shown through the use of 95% confidence intervals. Estimating the aggregated level of uncertainty present at facility and district levels was calculated using the svyratio function in the survey package in R, which uses the ratio estimation as described in Levy and Lemeshow.[23] The data collected at the national level represents the enumeration of the population at that level (rather than a sample), and therefore a simple average across the total number of doses delivered was taken (*b*). To obtain a total unit cost per dose, the unit costs for the facility, district and national level were aggregated.

$$b)\ unitcost_{national} = \frac{C}{Q}$$

The cost per dose was calculated for two denominators: the total number of doses delivered across all interventions and the total number of MR and OPV doses delivered. Most of the findings are presented as the cost per MR and OPV dose, as the nutritional components were only delivered in half of the districts. To calculate total costs, the sampling and volume-weighted mean unit cost per MR dose was multiplied by the total MR delivery volume for the campaign represented by Q (*c*).

$$c)\ totalcost_{svw} = unitcost_{svw} * \sum_{i=1}^{N} Q_i$$

The calibration method and alternative weights were used as sensitivity analyses. Calibration was used to test whether the sampled sites were an accurate representation of all sites that participated in the campaign. The calibration method adjusts the inverse probability of sampling weights using the volume of vaccine doses (MR and OPV) delivered at each site and the total MR and OPV delivery volume in the campaign. The calibration method was performed in R using the raking function.

In addition, we tested the outcomes' sensitivity to the use of sampling weights, by also calculating the unit cost using volume weights only. Due to the study's specific sampling criteria, the variation in sampling weights was large, and an estimation without them was performed in order to observe the effect of including the sampling weights. This estimate was equal to the sum of the total costs across all sites in the sample divided by the sum of the delivery volumes across all sites in the sample (*d*).[22] This estimate therefore still

includes volume weights, as is commonly recommended, but excludes the sampling weights as per (*a*). The use of simple averages in costing studies has been shown to be upwardly biased by between 12% and 113% and was not considered for use in this study.[24]

$$d)\ unitcost_{vw} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} Q_i}$$

Testing for significance between groups was conducted using two sample t-tests, bootstrap regression and Fisher's exact test. Two sample t-tests were conducted to test for statistical significance between various groups of facility level costs ($p<0.05$). A bootstrap regression using 1000 replications was also ran to reduce the size of confidence intervals and give a clearer indication of differences between groups. Fisher's exact test was used to test for significance association between categorical variables.

4. FINDINGS

4.1 CAMPAIGN IMPLEMENTATION

Campaign strategy and staffing

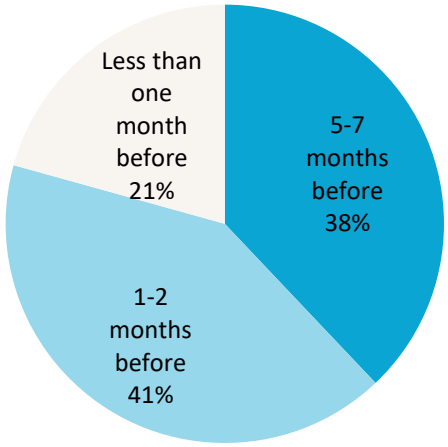
Temporary fixed sites were the most utilized delivery strategy (particularly schools) in the sampled areas, followed by facility-based, mopping up, and mobile teams conducting outreach in the communities. All districts used all potential delivery strategies, but their use differed by facility. Two hospitals did not deliver doses themselves, though their staff did engage in supervisory activities during the campaign. All other facilities delivered vaccines at schools, and many also offered the vaccines and interventions at the facility itself during the campaign. Other temporary fixed sites that were used included community centers, markets and open spaces. Of the 28 facilities that delivered vaccines during the campaign, 21 also used mobile sites or outreach activities (teams moving around in the communities) as a delivery strategy, and 24 conducted mop-up activities following the initial campaign period.

Of the health workers that were mobilized for the campaign at the sampled facilities, 70% were not on the facility payroll, or 55% when excluding community health workers and volunteers. Apart from the five hospitals included in the sample, at least half of the staff at almost all the facilities were involved in the campaign, and staff involvement at 11 of the 25 primary care facilities was more than 90%. As most of these were small facilities, this usually meant that they deployed fewer than ten staff (14 facilities) or between ten and twenty staff (9 facilities) during the campaign. In total, at the sampled facilities, 160 community health workers, 79 state enrolled community health nurses (SECHN), 72 maternal and child health (MCH) aides, 60 volunteers, 24 facility managers, 11 state community midwives, 10 nursing aides, and 36 other health workers, administrative staff and drivers were involved in the campaign. Of those not on the facility's payroll, 57% receive a regular but small stipend, while the others' only renumeration for the campaign was the per diem provided.

Campaign preparations

District offices started microplanning activities 6-7 months in advance, but at facility level, planning often only started in the two months leading up to its implementation (Figure 3). Those that started earliest included the hospitals and all facilities in Koinadugu. The start date signified a meeting of facility managers at district level or the start of microplanning activities. Up until the start of the campaign, most facilities participated in 2-3 meetings, and one or two trainings. Most facilities indicated that their list of targeted children had either been estimated based on the catchment population size, and a subsequent estimate for the number of children in the area had been prepared by the district office. Only two facilities had gathered information explicitly for the purpose of the campaign, from community health workers and the local schools.

Figure 3: Start of campaign preparations at facility level (n=29)



The amount of time that facility staff members spent on preparing for the campaign varied per district, and not by facility size. Facility staff attended 1-2 training sessions prior to the campaign. Staff underwent up to 12-24 hours of training depending on the district. Staff at the two facilities who did not deliver the interventions but participated in supervision received between 16 and 32 hours of training. In addition, staff spent time on the preparation of the campaign. Staff members at the facilities in Koinadugu were busiest preparing for the campaign in the month leading up to its implementation (55 hours per staff member on average), while in Tonkolili personnel spent only around six hours per person on campaign preparations. Most of that time was spent on social mobilization activities, followed by campaign management.

Campaign coverage

Administrative coverage data often showed coverage above 100%, as districts vaccinated more children than the target population (Table 5). Some districts reported experiencing problems with the M&E electronic database, and had trouble keeping track of population movements, especially that of children going to urban areas for schooling.[25] Especially at facility level, although the number of doses delivered was well-documented, target data was often missing or inaccurate. In some cases this resulted in improbably high or low coverage rates for the facility's catchment area. Coverage of above 100% was observed especially for OPV, Vitamin A and Albendazole. This may have been because MR was the main focus on the campaign, and a greater emphasis was placed both on getting the target population right, as well as on tallying and record keeping for MR. Due to these denominator issues, our results mainly focus on the cost per dose delivered rather than the cost per targeted child. Wherever we do analyze data against coverage, we use the MR survey data at district level as much as possible, as this is likely to be the most reliable source.

From the data it appears that districts that delivered additional nutrition interventions achieved similar MR coverage compared to those that delivered only the vaccines. Table 5 summarizes the district level coverage data reported in the different sources. The post-coverage survey only assessed MR, and so coverage for the other interventions could not be compared. Although no definitive conclusion can be drawn, the survey data does not seem to indicate that districts that delivered more interventions suffered lower MR coverage as a result. When analyzing facility level coverage data, no significant association between high facility level MR coverage (>95%) and the types of interventions delivered was found when using Fisher's exact test. However, due to the challenges around the facility administrative coverage data, this finding should be viewed with caution.

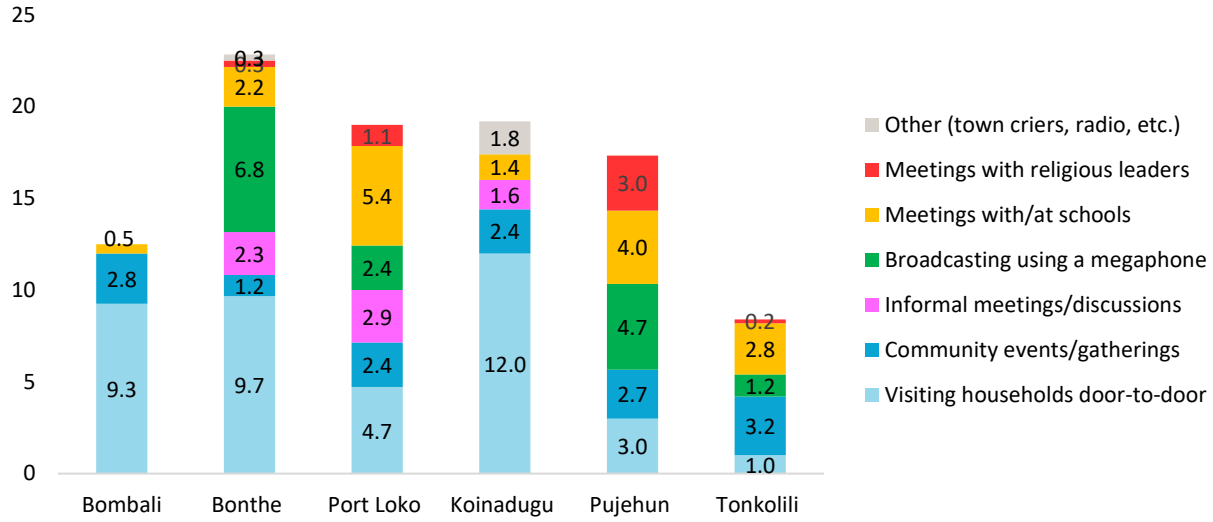
Table 5: Campaign coverage in sampled districts as per post-coverage survey and EPI report

	Post campaign-survey (card or recall)	Administrative data in EPI report			
	MR	**MR**	**OPV**	**Vitamin A**	**Albendazole**
Bombali	96%	95%	100%	98%	99%
Bonthe	98%	81%	117%	100%	99%
Port Loko	86%	95%	58%	94%	100%
Koinadugu	99%	94%	126%	N/A	N/A
Pujehun	70%	101%	127%	N/A	N/A
Tonkolili	97%	100%	103%	N/A	N/A

Social mobilization strategies

Across the six sampled districts, facilities conducted an average of 8-23 social mobilization activities in relation to the campaign. To raise demand for the upcoming campaign, community gatherings and meetings at schools and with religious leaders were organized in the month before the campaign, while many of the broadcasting and visits to households took place while the campaign was already ongoing. The average number of different activities conducted per facility in each sampled district is shown in Figure 4, ranging from 8 in Tonkolili to 23 in Bonthe. Many facilities indicated that if there had been more time or budget available, that they would have liked to have organized radio discussions or jingles, and they expressed a need for more megaphones and batteries, and additional per diem for community health workers.

Figure 4: The average number of social mobilization events per facility either before, during or after the campaign



4.2 TOTAL AND UNIT COST OF THE CAMPAIGN

Total cost of the campaign

The total economic cost of the campaign incurred by the ministry of health and health sector partners, excluding the cost of the vaccines and supplements, was estimated at $3,422,043. The total financial delivery cost of the campaign was $1,566,596 as shown Table 6. The total labor and other opportunity delivery costs were projected to be $1,855,448. Of the financial costs, 90% were incurred by the government at national, district and facility level, and the remainder were incurred by partners at national and district level. All costs are shown in 2019 SLL and USD.

Table 6: Total costs for the integrated MR campaign in Sierra Leone (2019 US$ and 2019 SLL)

	TOTAL COST	Vaccine and supplement cost	Operational cost: government and partners	Operational cost: government at all levels (national, district, facilities)
Financial cost	$ 3,943,200 (SLL 35,529,101,566)	$ 2,376,604 (SLL 21,413,725,910)	$ 1,566,596 (SLL 14,115,375,656)	$ 1,413,491 (SLL 12,735,868,635)
Labor and other opportunity costs	$ 1,855,488 (SLL 16,717,992,353)	-	$ 1,855,488 (SLL 16,717,992,353)	$ 1,770,276 (SLL 15,950,579,171)
TOTAL ECONOMIC COST	**$ 5,798,647 (SLL 52,247,093,919)**	**$ 2,376,604 (SLL 21,413,725,910)**	**$ 3,422,043 (SLL 30,833,368,009)**	**$ 3,183,767 (SLL 28,686,447,807)**

The total cost of vaccines, supplements and tablets used during the campaign, including freight and insurance costs, amounted to $2,376,604, as shown in Table 6. Of the 379,070 vials of MR received by the EPI, 311,587 were used or wasted during the campaign (82%). Table 7 shows the per dose cost for the vaccine or commodity and the shipping. The cost of freight and insurance fees for the vaccines amounted to $153,685. The wastage rate for the vaccine interventions was similar, at 4% for MR and 3% for OPV, while this varied between the nutritional interventions from less than 1% for albendazole tablets to 10% for the vitamin A supplements. The value of vaccines and commodities which were received but not used during the campaign was $503,196, of which $473,676 was from unused MR vaccines.

Table 7: Vaccine and commodity cost (2019 US$)

	MR	OPV	Vitamin A	Albendazole
Vaccine/commodity cost per dose	$ 0.66	$ 0.12	$ 0.02	$ 0.04
Intl shipping cost per dose	$ 0.05	$ 0.01	$ 0.001	$ 0.002
Total vaccine/commodity cost per dose	**$ 0.70**	**$ 0.13**	**$ 0.02**	**$ 0.04**
Doses delivered	2,991,405	1,254,135	440,229	375,130
Wastage	124,466	35,102	48,912	2,308
Total doses used	**3,115,871**	**1,289,237**	**489,141**	**377,438**
Vaccine/commodity cost per intervention	**$ 2,187,092**	**$ 162,089**	**$ 11,963**	**$ 15,460**
TOTAL VACCINE AND COMMODITY COST		**$ 2,376,604**		

Overall delivery cost of the campaign per dose

The operational cost per intervention delivered to a child (MR, OPV, Vitamin A, and albendazole) was US$0.69 (6219 SLL), of which US$0.31 were financial and US$0.38 were labor and other opportunity costs (Table 8). The cost of vaccines and commodities and related freight costs was equal to $0.47 of all doses delivered, resulting in a total economic cost per dose of $1.16, including these costs. Financial costs largely consisted of diems and travel allowances, followed by injection and safety supplies, and transport and fuel.

Table 8: Cost per dose of all interventions administered (2019 US$ and 2019 SLL)

	Cost per dose of all interventions administered (MR, OPV, VitA, Albendazole)
Financial cost	$ 0.31 ($0.31–$0.32) (SLL 2836)
Labor and other opportunity costs	$ 0.38 ($0.37–$0.38) (SLL 3383)

Economic cost (delivery costs only, excluding vaccines and commodities)	**$ 0.69 ($0.68–$0.70) (SLL 6219)**
Vaccines and commodities cost	$ 0.47 (SLL 4231)
Economic cost (including vaccines and commodities)	**$ 1.16 ($1.15–$1.17) (SLL 10,450)**

4.3 COMPARISONS BETWEEN SUBGROUPS

Cost per dose in districts that delivered all interventions versus vaccines only

As could be expected, the cost per dose delivered was lower in the districts that delivered all four interventions during campaign as the number of doses delivered in total was higher. Although half of the districts in the country delivered nutrition supplements in addition to vaccine doses, many costs were similar across districts. For example, vaccination teams were of equal size, and health workers in districts that delivered more interventions did not receive additional per diems. Table 9 shows the cost per dose of any intervention delivered in districts that delivered only vaccine doses (MR and OPV) compared to districts that delivered all four interventions (MR, OPV, Vitamin A supplements, Albendazole). It shows that both the financial as well as labor (and other opportunity) costs were lower on a per dose basis in those districts that delivered more interventions because of the increased volume delivered using similar resources.

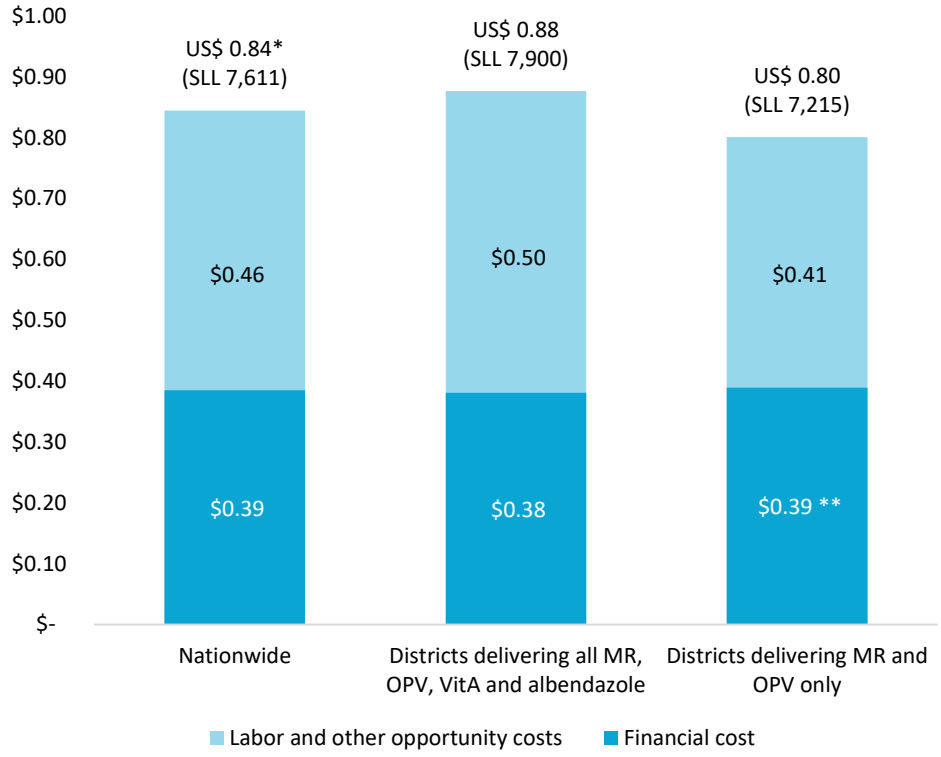
Table 9: Cost per dose delivered with 95% confidence intervals incurred by the MoHS and health sector partners (2019 US$ and 2019 SLL)

	Operational cost per dose delivered (MR, OPV, VitA, and albendazole)	in districts that delivered MR, OPV, VitA, and albendazole	in districts that only delivered MR and OPV*
Financial cost	**$ 0.31 ($0.31–$0.32) (SLL 2836)**	**$ 0.28 ($0.27–$0.28) (SLL 2505)**	**$ 0.38 ($0.38–$0.39) (SLL 3453)**
Labor and other opportunity costs	**$ 0.38 ($0.37–$0.38) (SLL 3383)**	**$ 0.36 ($0.00–$0.76) (SLL 3237)**	**$ 0.41 ($0.40–$0.41) (SLL 3668)**
ECONOMIC COST	**$ 0.69 ($0.68–$0.70) (SLL 6219)**	**$ 0.64 ($0.63–$0.64) (SLL 5742)**	**$ 0.79 ($0.78–$0.80) (SLL 7121)**

When analyzing costs using equal denominators, the financial cost per vaccine dose delivered was similar in districts which delivered all interventions versus vaccines only, while the opportunity cost (mainly consisting of paid and volunteer labor) was higher in districts which delivered vaccines and nutrition

interventions. The financial delivery cost per MR and OPV dose varied only slightly between districts which delivered all four interventions ($0.38) and the districts that delivered the vaccines only ($0.39) as can be seen in Figure 5. However, labor and other opportunity costs were higher in districts which delivered all interventions.

Figure 5: Breakdown of the economic cost per MR and OPV dose depending on which interventions were delivered in the district (2019 US$ and 2019 SLL)



** Due to rounding, this total appears to not add up exactly*

*** Because of the change in allocating national level costs (across vaccine doses only), the financial cost per vaccine dose in districts that delivered only MR and OPV is slightly higher in Figure 5 ($0.39) than in Table 9 ($0.38).*

Volume delivered

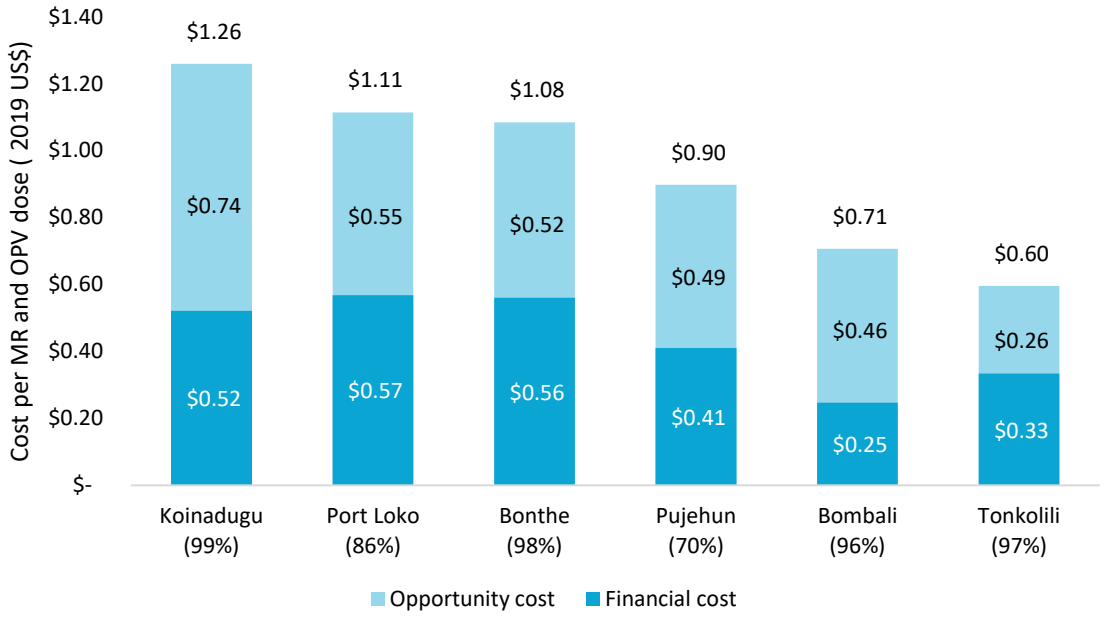
The financial and economic cost per MR and OPV dose delivered at facilities varied with the number of doses delivered by the facility. Combining the facility and corresponding district level costs for each facility, a downward trend in the cost per dose can be seen in Figure 6, as the volume MR and OPV doses delivered increases. Due to the small sample size, we did not attempt regression analysis for further study of the relationship between costs and volume delivered.

Figure 6: Facility and district level cost per MR and OPV dose and doses delivered per facility (2019 US$)

Districts

Among the six sampled districts, the financial and economic cost per dose varied widely. Two of the three districts with the highest costs per dose were those with geographical challenges and lower MR coverage. The two districts which were selected due to geographical challenges, had the lowest reported MR coverage, and also had among the highest economic cost per MR and OPV dose ($1.09-1.26) compared to the four others ($0.60-$1.11). Figure 7 shows that the opportunity cost per dose was also substantially higher in the hilly district of Koinadugu ($0.74) than the others (below $0.55). Port Loko, which had the second highest economic cost per dose and did not have district-wide geographical challenges, reported a far lower coverage of OPV (58% of children targeted) than other districts (over 99%). Bombali, which had the lowest financial cost per dose, reported substantially lower transport costs than the other districts. The DHMT reported $321 of transport and fuel costs compared to $1190–$14,850 reported by other DHMTs, and two of the four sampled facilities conducted their activities entirely on foot and incurred no transport and fuel costs.

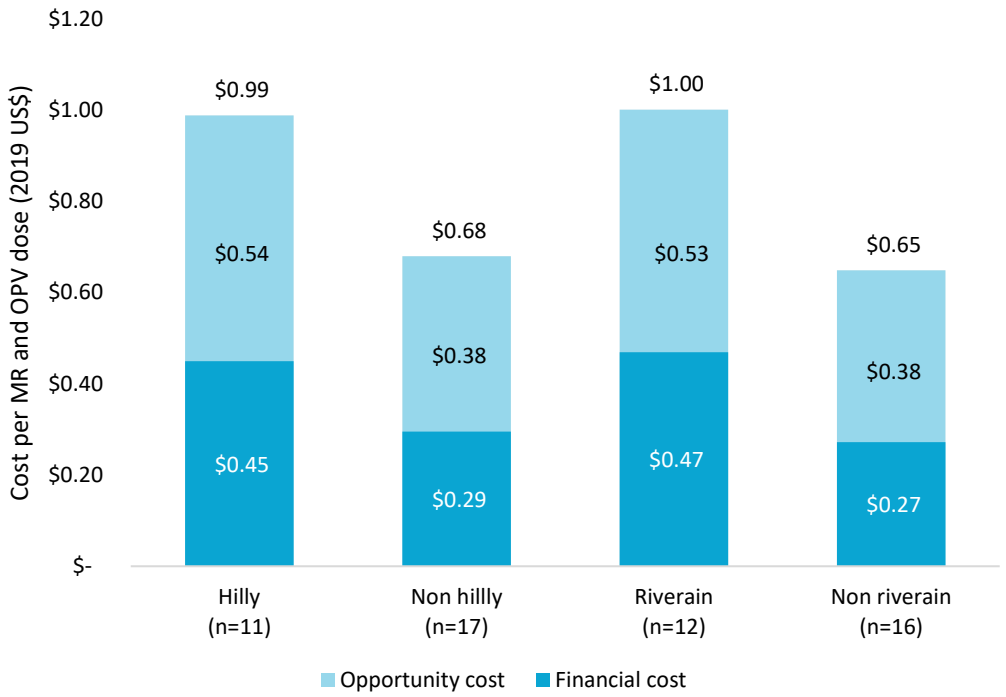
Figure 7: Breakdown of the economic cost per MR and OPV dose by district including costs incurred at all levels (% MR coverage) (2019 US$)



Geographical challenges in the facility catchment area

The financial facility and district level cost per dose for facilities in hilly or riverain areas was over 50% higher than for facilities not located in these types of areas. Eleven facilities self-reported as being located in hilly or mountainous areas, including all five facilities in Koinadugu district. The economic cost per dose was also higher in these hilly areas ($0.99) compared to non-hilly areas ($0.68). Figure 8 shows that this pattern was also seen with the financial cost per dose also being higher in hilly areas ($0.45) compared to non-hilly areas ($0.29). A similar effect was seen for the economic cost per dose among the 12 facilities reported as being in riverain/island areas ($1.00) compared to the non-riverain/island areas ($0.65). No significant differences were found between groups using either two-sample t tests or bootstrap regression. A significant association ($p<0.05$) was found between lower MR coverage (<95%) and facilities being in hilly/mountainous areas using a one-sided Fisher's exact test, though due to weak facility level coverage data this finding must be viewed with caution.

Figure 8: Breakdown of the facility and district level economic cost per MR and OPV dose by characteristics of facility location (2019 US$)



Costs in facilities which did not deliver interventions

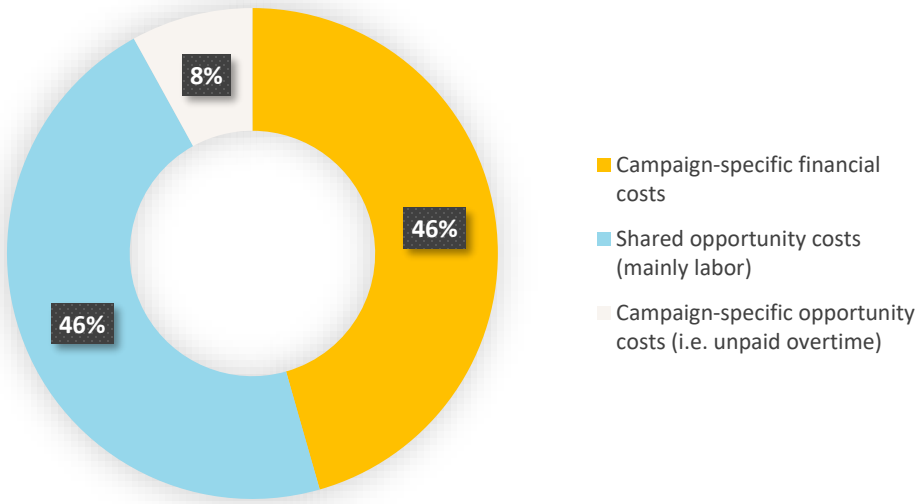
Not all facilities which were involved in the campaign administered the interventions, but incurred costs through the provision of AEFI management, campaign management, supervision and training. Two facilities in the sample, both hospitals, did not deliver interventions during the campaign and were not included in the main analysis, but provided other support before and during the campaign for activities such as supervision and training. The average total financial cost at these hospitals was 47% lower than that of the hospitals in the sample which conducted service delivery. The gap in the average total opportunity cost was even greater, the average being 60% lower at the two hospitals which didn't administer interventions compared to the hospitals which did.

4.4 BREAKDOWN BY COST COMPONENT

Shared and campaign-specific costs

Shared costs accounted for the majority of opportunity costs (85%) and just under half of the total economic costs (46%), as per Figure 9. Campaign-specific financial costs include all financial expenditures that were incurred specifically for the campaign, such as per diems, fuel costs, etc., and these costs made up 46% of the total economic costs. The remainder consisted of opportunity costs, which includes the value of resources for which no campaign-specific financial expenditure was incurred. Shared opportunity costs consisted mostly of labor within normal working hours which was spent on campaign activities (93%), as well as the use of vehicles, building space, equipment and utilities. Campaign-specific opportunity costs were composed entirely of unpaid overtime spent on the campaign. Many (paid and unpaid) health workers worked longer days during the campaign than they would during a regular workweek, for which they received no additional compensation.

Figure 9: Breakdown of the economic cost per MR and OPV dose by campaign-specific and shared costs (2019 US$)

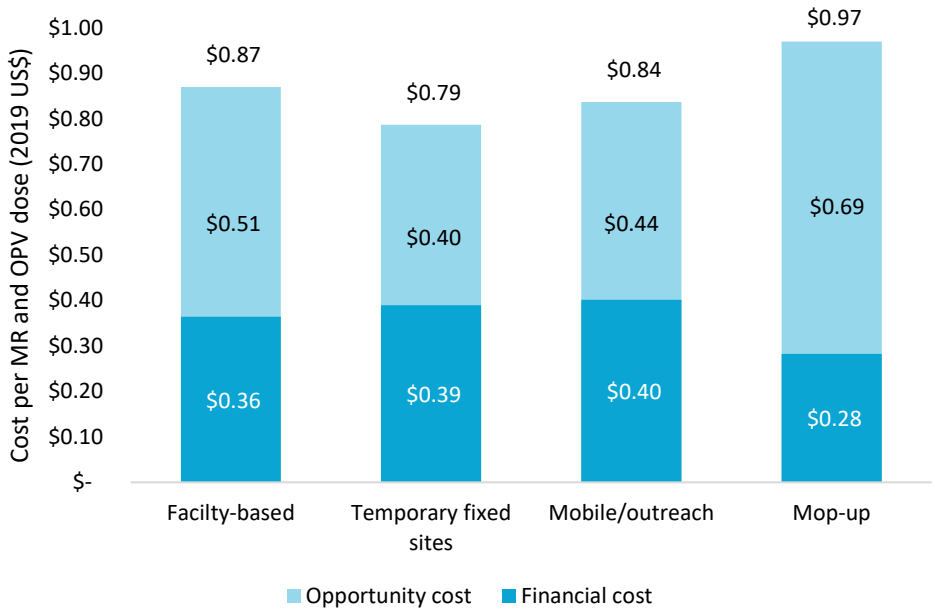


Delivery strategy

The financial delivery cost per dose was highest for the two strategies for which teams sometimes incurred transports: mobile/outreach and temporary fixed sites. Figure 10 shows that the highest financial cost per dose was incurred through service delivery by mobile teams ($0.40) followed by temporary fixed sites ($0.39), mainly due to the transport costs incurred for these strategies. However, because volume delivered through these strategies was relatively high, the financial cost per dose was only slightly higher than that of the low volume delivery strategies (facility-based and mop-up). The financial cost per dose for mop-up ($0.28), the strategy through which the fewest doses were delivered, was lower than for the other strategies ($0.36–$0.40) particularly because per diem was not given for mop-up activities.

The economic cost per dose delivered was highest for the mop up delivery strategy ($0.97), followed by facility-based delivery ($0.87), mainly due to lower delivery volume. The higher proportion of per dose opportunity costs for facility-based delivery is due to the labor cost per dose delivered through this strategy being higher than for other strategies during the campaign as fewer doses were administered delivered at facilities and labor costs for higher ranking staff were allocated to facility-based when the strategy they worked on was unknown (e.g. assumed the facility manager likely stayed at the facility and did not participate in outreach). Facility-based service delivery did include certain other opportunity costs that were not included for other delivery strategies, such as the cost of building space and utilities used, but these were generally very small. A breakdown of the delivery strategy costs at facility level can be found in Annex III: Breakdown by delivery strategy.

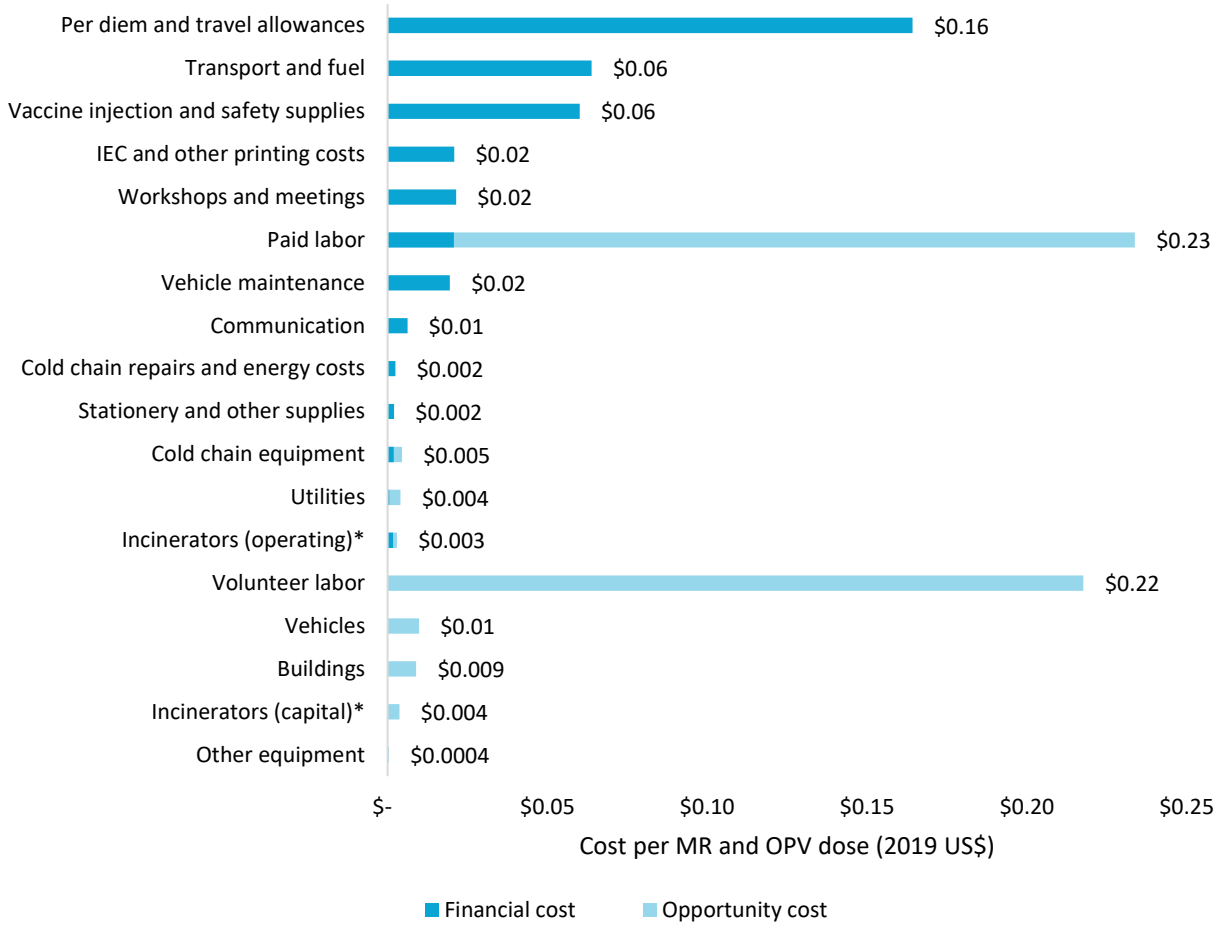
Figure 10: Breakdown of the economic cost per MR and OPV dose by delivery strategy (including costs incurred by partners and at all levels) (2019 US$)



Resource type

The largest resource type component of the financial cost per dose were per diems and travel allowances (43%), while paid and volunteer labor accounted for 94% of the opportunity cost per dose. Figure 11 details the breakdown of the economic cost per MR and OPV dose delivered when split between financial and opportunity costs and by resource type. The financial cost per dose is driven by per diems and travel allowances (43%), followed by transport and fuel (17%) and injection and safety supplies (16%). Volunteer labor and paid labor comprised 94% of opportunity costs. Volunteer labor constituted a slightly higher proportion of the overall opportunity per dose than paid labor (47% to 46%). The opportunity cost of volunteers was higher than that of paid labor in 19 of the 28 sampled facilities, reflecting the time spent on the campaign by volunteers and members of staff who were not on payroll. Capital costs accounted for a very small proportion of costs, less than 1% of the financial cost per dose and 3% of the economic cost. A full breakdown of the costs can be found in Annex V: Breakdown by resource type.

Figure 11: Breakdown of the economic cost per MR and OPV dose by resource type (2019 US$)

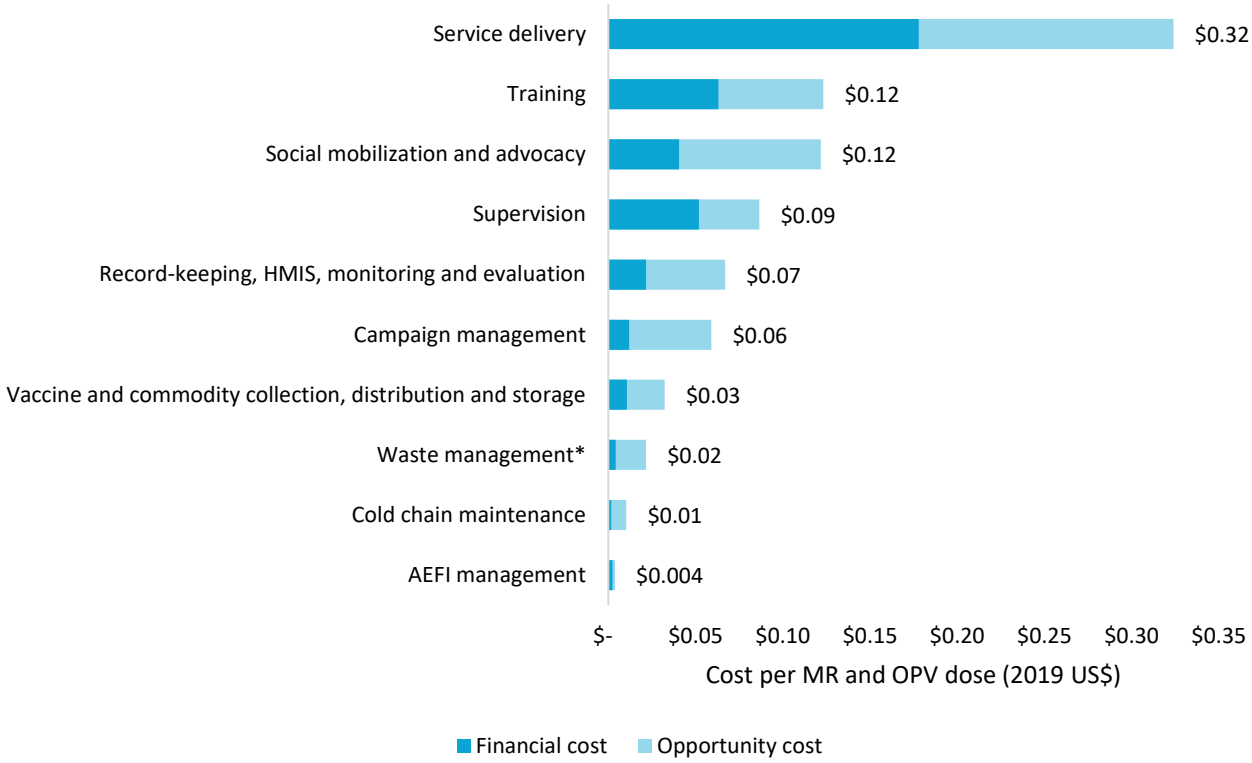


** Denominator – number of MR doses delivered*

Cost activity

Service delivery costs accounted for 46% of the financial and 32% of the opportunity cost per MR and OPV dose. Figure 12 shows the cost per MR and OPV dose delivered by cost activity. The various service delivery cost activities made up almost half of the financial cost per dose (46%) and third of the opportunity cost per dose (32%). Aside from service delivery, training made up the largest segment of the financial cost per dose (16%), followed by supervision (14%). Social mobilization constituted 18% of the opportunity cost per dose and the highest single component, driven by the hours spent on various social mobilization events before and during the campaign by health workers and volunteers. A full breakdown of the costs can be found in Annex VI: Breakdown by cost activity.

Figure 12: Breakdown of the economic cost per MR and OPV dose by cost activity (2019 US$)

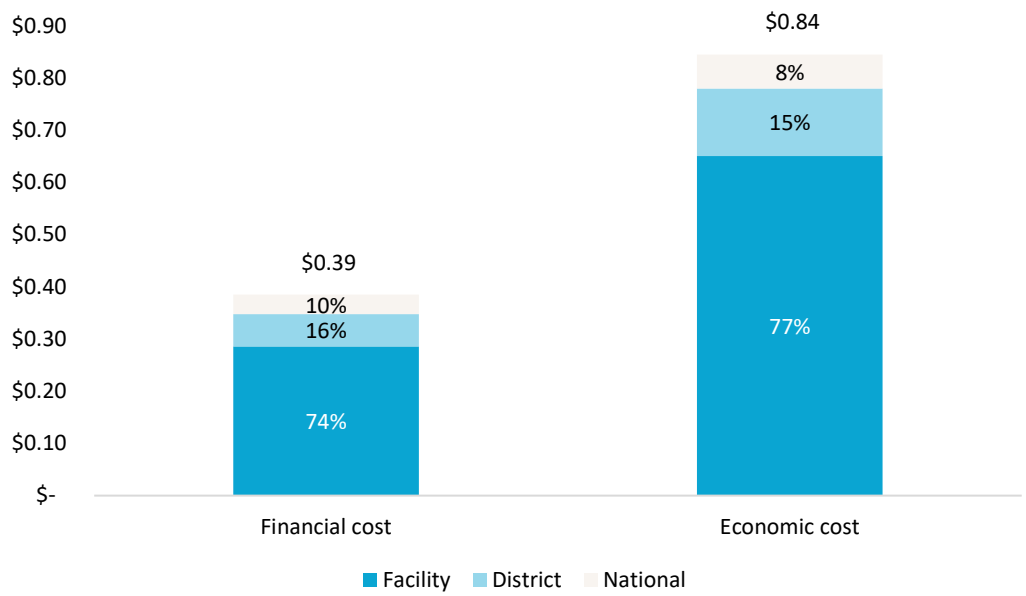


** Denominator – number of MR doses delivered*

Costs by level at which they were incurred

The majority of costs were incurred at facility level, including 74% of financial costs. When stratifying the costs by the level they were incurred at, 77% of the economic cost was incurred at facility level, 15% at district level and 8% at national level, as shown in Figure 13. Costs incurred by national and district level partners amounted to a $0.04 financial cost and a $0.06 economic cost per MR and OPV dose delivered. Almost two thirds of the economic costs incurred by national and district partner costs were financial (64%), consisting largely of WHO contractual service costs (60%) and transport costs (30%). Shared opportunity costs made up 34% (mostly vehicles and staff) and 2% campaign-specific opportunity costs (overtime).

Figure 13: Cost per MR and OPV dose and the proportion incurred at different health system levels (2019 US$)



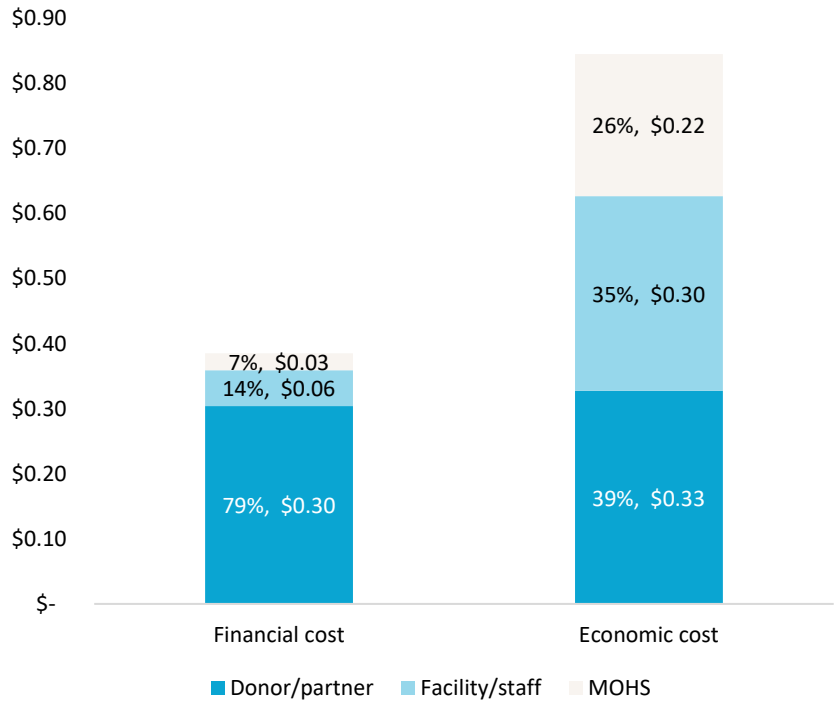
The economic cost per MR and OPV dose delivered was $0.65 ($0.51–$0.79) at facility level, $0.13 ($0.08–$0.18) at district level and $0.06 at national level. The variance in the cost per dose at facility and district level can be seen in Figure 14, with variance of $0.838–$0.851 present in the total cost per dose of $0.84. A higher level of variance is evident in the facility level cost per dose.

Figure 14: Economic cost per MR and OPV dose by level and in total with 95% confidence intervals (2019 US$)

Cost by who incurred it

Most financial funding for the campaign was provided by partners or donors, while MoHS staff and volunteer labor constituted almost half of the economic costs. Of the financial expenditures, 79% came from donors and partners, followed by 14% from staff and health facilities, and 7% from the MoHS as shown in Figure 15. Staff working at all levels, as well as individual health facilities, also made out of pocket contributions towards items such as airtime expenses, transport costs and stationery supplies. These financial contributions amounted to $0.06 per dose, which is far lower than the cost for per diems and travel allowances given to health workers for the campaign ($0.16 per dose). Almost half of the economic cost pertained to the paid and unpaid labor of facility, district and national level staff (49%), while 5% consisted of partner staff labor costs. Where it was not clear who incurred the costs, MoHS was chosen as the default. It is important to differentiate that who the costs were incurred by is not the same as the funding sources, and that these costs cannot be compared to the campaign budget. For example, campaign budgets may include capital investments such as cold chain equipment and vehicles, while costing studies may annualize such capital expenditures.

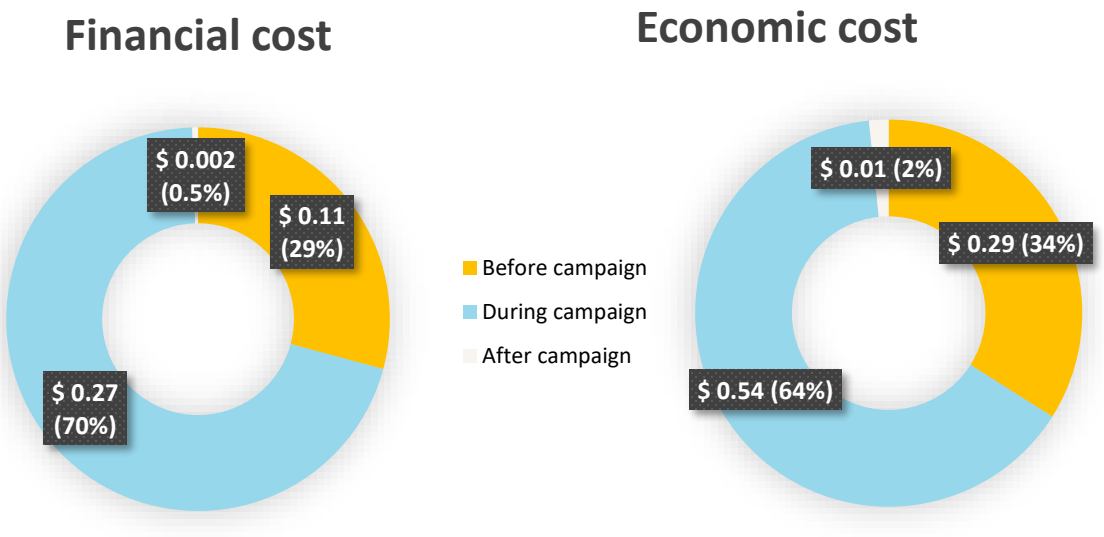
Figure 15: Cost and proportion per dose of MR and OPV by funding source (2019 US$)



Time periods

Most costs were incurred during the week of the campaign, with a third being incurred prior to the campaign beginning and a small proportion after the campaign had concluded. The majority of the costs (70% of financial costs and 59% of economic costs) were incurred during the week of the campaign (10th-16th June 2019), and approximately a third of costs had been incurred prior to the start of the campaign (on or before 9th June 2019), as seen in Figure 16. Less than 1% of financial costs and 2% of economic costs were incurred after the conclusion of the campaign (17th June 2019 or later), and the latter mostly consisted of labor costs.

Figure 16: Proportion of financial and economic costs incurred by time point (%)



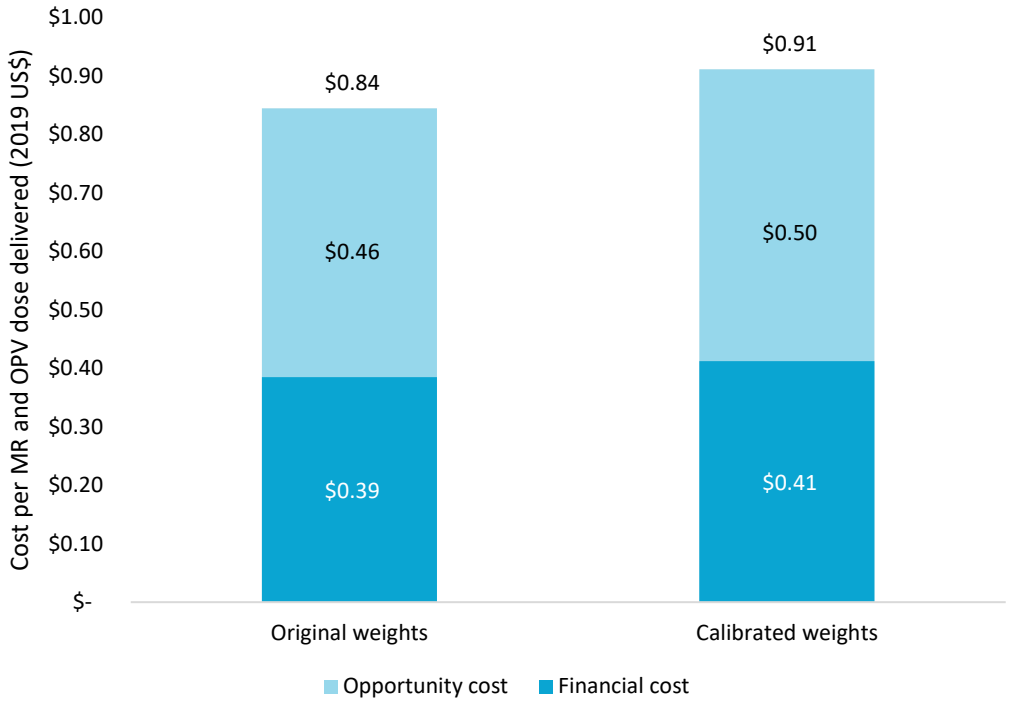
4.5 SENSITIVITY ANALYSIS AND SCENARIO TESTING

Calibration estimator

USING CALIBRATED INVERSE PROBABILITY OF SAMPLING WEIGHTS FOR THE FACILITIES IN THE SAMPLE, THE FINANCIAL AND ECONOMIC COST PER MR AND OPV DOSE DELIVERED INCREASED AS SEEN IN FIGURE 17. REWEIGHTING THE FACILITY LEVEL SAMPLING WEIGHTS USING THE TOTAL VOLUME OF MR AND OPV DOSES DELIVERED IN THE CAMPAIGN INCREASED THE FACILITY LEVEL COST PER MR AND OPV DOSE DELIVERED BY 10% RESULTING IN AN OVERALL INCREASE IN THE ECONOMIC COST PER DOSE DELIVERED FROM $0.84 TO $0.91. THIS MEANS THAT THE UPDATED SAMPLING WEIGHTS GIVE GREATER EMPHASIS TO THE FACILITIES WITH A HIGHER COST PER DOSE, AND THAT THESE WERE CONSIDERED MORE REPRESENTATIVE OF THE NATIONAL AVERAGE THAN THE LOWER COST PER DOSE SITES IN OUR SAMPLE. A CONTRIBUTING FACTOR TO THIS IS THAT THE ORIGINAL SAMPLING WEIGHTS GAVE A LOWER WEIGHTING TO FACILITIES IN BONTHE AND KOINADUGU DISTRICTS WHICH WERE SELECTED PURPOSIVELY DUE TO THEIR HILLY OR RIVERAIN CHARACTERISTICS. AFTER CALIBRATING, ALL FACILITIES IN THESE DISTRICTS RECEIVED A HIGHER WEIGHTING, SEVERAL OF WHICH HAD HIGH UNIT COSTS. ALL FACILITIES WITH ORIGINAL INVERSE PROBABILITY OF SAMPLING WEIGHTS OF OVER 78 (AND UP TO 306) RECEIVED A LOWER WEIGHTING AFTER CALIBRATION. A COMPARISON OF THE ORIGINAL AND CALIBRATED WEIGHTS CAN BE VIEWED IN

Annex VI: Original and calibrated sampling weights.

Figure 17: Breakdown of the economic cost per MR and OPV dose using the original and calibrated sampling weights (2019 US$)



Comparing weighting methods

In order to compare the impact that different unit cost calculation methods have, a comparison was made between the use of volume and sampling weights (as per the Findings section), and the use of volume weights only. The comparison in Table 10 shows that when only volume weights are used, the total cost per MR and OPV dose was $1.02, which is higher than the $0.84 estimates that included both volume and sample weights. The sample included two districts that had been selected purposively due to geographic challenges, and which generally had a higher cost per dose. When using volume weights only, the high volume-facilities in those two districts receive more weight, which pushes up the volume weighted average economic cost per dose of the sample by 20%. This is a clear argument for the inclusion of sampling weights to prevent an upward bias when utilizing a sampling strategy that specifically incorporates high cost sites. However, our sampling strategy also included specific criteria for the type of health facility (public and non-public health facilities in rural and urban areas), which drove sampling weights. In practice, many facilities that officially had different classifications had similar characteristics, which means that the effect on sampling weights may have been more arbitrary. Decreases of 51% and 70% in sampling weights were seen among the rural public facilities in Bombali, Port Loko, Pujehun and Tonkolili which initially had the highest sampling weights. The proportion of weight allocated to facilities in Bonthe and Koinadugu (purposively sampled due to their geographic challenges) increased by up to 90 times, with the highest increases seen among an urban hospital and urban facilities.

Table 10: Cost per MR and OPV dose calculated using volume weights only (2019 US$)

	Operational cost per dose delivered (MR, OPV, VitA, and albendazole)		Operational cost per vaccine dose delivered (MR and OPV)	
	Volume weights only	Sampling + volume weights	Volume weights only	Sampling + volume weights
Financial cost	**$ 0.35**	**$ 0.31**	**$ 0.44**	**$ 0.38**
Opportunity cost	**$ 0.45**	**$ 0.38**	**$ 0.58**	**$ 0.46**
Economic cost	**$ 0.80**	**$ 0.69**	**$ 1.02**	**$ 0.84**

Scenario testing

Paying per diems to staff for mop-up activities increases the facility level financial cost per dose by 6% to $0.30. Using the standard daily rate of per diem paid to staff for the seven days of the campaign, it was found that by paying staff for each day of mop-up activities they were involved in increased the total financial cost per facility by a median of 5% and up to 12%, excluding the two facilities which did not conduct mop-up activities.

5. DISCUSSION

The main findings of this study align with global evidence, and although much lower than donor estimates of the operational cost of a campaign, the unit costs are comparable with similar studies. Per diems followed by transport costs and vaccine injection and safety supplies were found to be the main financial delivery cost drivers for this campaign, while labor was the largest driver of opportunity costs. The financial cost drivers are in line with a costing study of a yellow fever campaign in Côte d'Ivoire which identified consumable supplies and per diems to be the largest cost drivers, though the definition of consumables was wider, and the cost was higher than that of per diems. This campaign also used a fixed site urban delivery strategy which could explain the difference in transport costs.[26] Personnel costs (labor costs and per diems) accounted for 73% of economic delivery costs in the current study, similar to a study of supplementary immunization activities (SIAs) to deliver measles vaccines in Anambra state, Nigeria, where personnel costs constituted 69% of delivery costs, though this did not include per diems for supervision or training.[27] The financial delivery cost per MR dose delivered ($0.52) is far below the US$1.00 per child estimated by the Measles & Rubella Initiative, and Gavi's estimate of the operational cost of a campaign (US$0.80 per child), though this is an average based on a wide range of data for many LMICs and different types of campaigns, using decades-old cMYP estimates.[6] When comparing our unit costs to previous campaign costing studies, our financial cost per MR and OPV dose delivered ($0.39) is comparable to that of the yellow fever campaign in Côte d'Ivoire ($0.43, USD 2020), and the economic cost per MR and OPV dose delivered ($0.84) is similar to the $0.81 (USD 2016) cost per child immunized in measle vaccine SIAs in Nigeria, though the latter did not include vaccine supplies or national level costs.

This study showed the importance of opportunity cost borne by the existing health system resources, particularly in terms of labor for the campaign, though the majority of financial costs were donor funded. Expenses that were paid out of pocket by facility staff or by health facilities themselves, rather than being from funds received for the campaign, were also captured. Some analyses which were originally planned were

not able to be carried out due to the small size of the subgroups, e.g. cost by facility type and the cost depending on challenges experienced by facilities during to the campaign.

This study analyzed the cost of the campaign in districts which delivered vaccines only compared to districts which delivered vaccines and nutritional interventions. Integrating nutritional interventions was not found to result in a higher financial unit cost, but a higher opportunity cost (driven by labor) was found in districts which delivered these additional interventions, though the difference was not found to be significant. With integrated campaigns more likely to be deployed as a catch-up strategy following the COVID-19 pandemic, our cost evidence provides a first glance at the additional cost of co-delivery in campaigns. However, it is important that more costing evidence is developed around the cost as well as the effectiveness and quality of various types of integrated campaigns. This was not possible in this study as reliable coverage data for all campaign interventions and at all levels was unavailable.

Several learnings and recommendations have been developed from this study for future research and methods. We strongly recommend future studies to focus on analyzing the costs of co-delivered interventions with the coverage and quality achieved, so that the economics of co-delivery can be further understood. The practical learnings from conducting this study have been incorporated into a subsequent campaign costing study in Nigeria and methodological guidance for immunization campaign costing. These include the use of Excel-based questionnaires, shortening the length of the questionnaires to prevent interviewee fatigue and excluding cost components such as utility costs and building space used which constituted a very small proportion of the overall cost.

6. LIMITATIONS

This study has limitations due to its limited sample size, recall bias, and the impact of the COVID-19 pandemic on data collection. The strength of the findings is limited by the sample size of 30 facilities, of which only 28 delivered the interventions, representing only a limited share of the total number of facilities involved in the campaign. Recall bias may also have impacted the quality of the data due to the length of time which had elapsed between the campaign and data collection. While the campaign was implemented in June 2019, data collection commenced in October 2019, with the last facilities visited in February 2020. Data limitations also limited our ability to analyze our cost data against output indicators. The COVID-19 pandemic also impacted our ability to collect more detailed data from the national level government and partners as these agencies were focused on responding to the pandemic and the opportunities for in-person interviews were limited.

7. CONCLUSION

The cost evidence generated from this study can be used for future planning and budgeting of campaigns in Sierra Leone and similar settings. With evidence on the cost implications of integrated campaigns lacking in the literature, this study provides timely and relevant data on delivering multiple vaccine and other interventions to similar target populations. The findings of this study show that integration of nutrition supplements in immunization campaigns can be done at similar financial costs, though at greater opportunity costs (mainly labor). However, this is the first and only study to analyze the cost of integrated campaigns, more country studies are needed to confirm these results. In addition, other studies should analyze the cost against the quality of integrated campaigns as well.

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ANNEX I: NAMES OF PARTNERS INCLUDED IN STUDY

Partner name	Level of health system
CARE	District
Concern/Saving Lives	District
CUAMM	District
Goal-SL	District
International Rescue Committee (IRC)	District
Lion Heart	District
Médecins Sans Frontières (MSF)	District
Restless Development	District
Save the Children	District
UNICEF	National
WHO	National
World Hope	District

ANNEX II: CALCULATION OF RESOURCE TYPE COSTS

OPERATING COSTS

		Financial cost *financial outlays incurred by actors included from a payer perspective: MoHS, partners, health sector providers, facilities*	**Economic cost** *opportunity costs from a payer perspective: MoHS, partners, health sector providers and facilities*	
	Definition	**Campaign-specific financial cost**	**Campaign-specific economic cost**	**Shared costs (economic)**
Paid labor	Allocation of salaried labor to campaign-related activities. Salaries are fully loaded thus including any regular fringe benefits.	Any wages paid to day laborers to for example help out with loading and unloading of vaccines or dig waste disposal pits.	Staff overtime during the campaign. Overtime was defined as any additional time spent working than during a regular, non-campaign working day.	Allocation of salaried labor to campaign-related activities. Salaries are fully loaded thus including any regular fringe benefits. Immunization staff only, excluding cleaners, cooks, security staff, and other staff who spent less than 50% of their time on the campaign during the campaign week. Regular (non-campaign related) stipends are also included here. The grade 1 salary amount was not provided and calculated based on the percentage decrease between other grades.
Volunteer labor	Estimation of the market value of volunteer labor used for campaign-related activities. Includes unpaid health workers.	*N/A*	Market value of volunteer labor used for campaign-related activities, estimated using average day laborer's wage.	For unpaid health workers regularly present at a health facility: average salary for the equivalent cadre is used.

		Financial cost *financial outlays incurred by actors included from a payer perspective: MoHS, partners, health sector providers, facilities*	**Economic cost** *opportunity costs from a payer perspective: MoHS, partners, health sector providers and facilities*	
Per diem and travel allowances	Any allowances paid to campaign staff and health workers for campaign-related activities.	Allowances paid to campaign staff, health workers (whether paid or unpaid) and community volunteers for campaign-related activities.	*N/A*	*N/A*
Vaccines, vitamin A and albendazole	Cost of vaccines and commodities delivered	Cost of vaccines (including insurance, freight and wastage), vitamin A supplements and albendazole tablets and other health campaign commodities procured or co-financed by the country, including wastage.	*N/A*	*N/A*
Vaccine injection and safety supplies	Cost of supplies used for the administration of vaccines for the campaign.	Cost of auto-disabled syringes, diluent, reconstituting syringes, safety boxes, cotton wool, hand sanitizer, disposal bags, and/or other supplies used for administration of interventions for the campaign, e.g. water for OPV and tablet administration.	*N/A*	*N/A*
Stationery and other supplies	Cost of stationery and other supplies for the campaign.	Cost of stationery and other supplies used for the campaign.	*N/A*	*N/A*
Transport and fuel	Cost of using public transport,	Cost of taxis, vehicle, motorcycle and/or boat hire, and the cost of	*N/A*	*N/A*

		Financial cost *financial outlays incurred by actors included from a payer perspective: MoHS, partners, health sector providers, facilities*	**Economic cost** *opportunity costs from a payer perspective: MoHS, partners, health sector providers and facilities*	
	hiring vehicles, and purchasing fuel for the campaign.	fuel for campaign-related transport.		
Vehicle maintenance	Cost of maintaining vehicles used for campaign-related activities.	Cost of maintaining carried out on vehicles (of all types) used for campaign-related activities either during or within 30 days prior to the campaign.	*N/A*	*N/A*
Cold chain repairs and energy costs	The cost of repairing existing cold chain equipment and running the cold chain.	Any repairs to cold chain equipment performed especially for the campaign.	*N/A*	*N/A*
IEC and other printing costs	The cost of campaign-related information, education and communication (IEC) materials for the campaign.	The cost of printing immunization cards, training materials, posters, tally sheets, radio jingles, tv ads and other materials that are campaign-related.	*N/A*	*N/A*
Utilities	Costs related to building overheads, including	*N/A*	*N/A*	Utility costs incurred during the duration of the campaign, e.g., electricity bill in facilities and DHMTs.

		Financial cost *financial outlays incurred by actors included from a payer perspective: MoHS, partners, health sector providers, facilities*	**Economic cost** *opportunity costs from a payer perspective: MoHS, partners, health sector providers and facilities*	
	maintenance, and utilities (but excluding cold chain energy costs).			
Workshops and meetings	Costs related to organizing campaign-related workshops, trainings and meetings.	Costs related to workshops, trainings and meetings organized for the campaign, including the venue and refreshments provided on the day, but related transport costs, per diems or printing of training materials is included under other line items.	*N/A*	*N/A*
Communication	Costs related to purchasing airtime and mobile data for the purpose of the campaign.	Costs related to purchasing airtime and mobile data for the purpose of the campaign.	*N/A*	*N/A*
Incinerator energy costs	Costs of running incinerator during the campaign.	Additional incinerator running costs specifically for the purpose of the campaign.	The cost of running the incinerators during a non-campaign week, assuming 100% was this usage for be campaign specific during the campaign week.	*N/A*

CAPITAL COSTS

		Economic cost *opportunity costs from a public health sector and partners perspective (in addition to the financial costs): MOH, partners health sector providers and facilities*
	Definition	**Shared costs (economic)**
Cold chain equipment	Value of all cold chain equipment used to store and transport vaccines. Solar panels and generators used to power the cold chain are also included here.	Depreciation of existing cold chain equipment used to store and transport the campaign's vaccines Share of the annualized cost of existing cold chain equipment
Vehicles	Value of all vehicles and modes of transport (could include cars, motorcycles, boats, bicycles, tricycles, camels)	Depreciation of existing vehicles attributed to the campaign Share of the annualized cost of existing vehicles attributed to the campaign
Other equipment	Value of other equipment, such as computers, printers, peripherals, phones, incinerators, other medical equipment used for campaign-related activities.	Depreciation of existing equipment attributed to the campaign Share of the annualized cost of existing equipment attributed to the campaign
Buildings	Value of building space used to deliver and store vaccines.	Opportunity cost of using building space for campaign Share of the annualized cost of building space attributed to the campaign

VACCINE AND COMMODITY FREIGHT COSTS

As international shipment costs could not be obtained, global level assumptions were used. It was assumed that the additional cost of freight and insurance fees for the vaccines amounted to 7% of vaccine price, as per the PATH Vaccine Cost Calculator.[28] A shipping cost equivalent to 4% of the price of the albendazole tablets and vitamin A supplements was added for these two interventions, in line with the ratio of albendazole tablet costs to shipping costs from an economic evaluation systematic review.[29] As per the Gavi application for the campaign, a 2% freight cost was applied to the prices of the syringes and safety boxes.[30]

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ANNEX III: BREAKDOWN BY DELIVERY STRATEGY

Level	Financial cost per MR and OPV dose delivered				Economic cost per MR and OPV dose delivered			
	Facility-based	Temporary fixed sites	Mobile/outreach	Mop-up	Facility-based	Temporary fixed sites	Mobile/outreach	Mop-up
Facility	$ 0.27 ($0.19–$0.36)	$ 0.30 ($0.25–$0.36)	$ 0.30	$ 0.19	$ 0.68 ($0.50–$0.87)	$ 0.61	$ 0.64	$ 0.79
District	$ 0.05	$ 0.05	$ 0.06	$ 0.05	$ 0.12	$ 0.12	$ 0.13	$ 0.12
National	$ 0.04	$ 0.04	$ 0.04	$ 0.04	$ 0.07	$ 0.06	$ 0.06	$ 0.06
Total	$ 0.36 ($0.36–$0.37)	$ 0.39 ($0.39–$0.39)	$ 0.40 ($0.40–$0.41)	$ 0.28 ($0.28–$0.29)	$0.87 ($0.68–$0.87)	$ 0.79 ($0.78–$0.79)	$ 0.84 ($0.83–$0.84)	$ 0.97 ($0.96–$0.98)

ANNEX VI: BREAKDOWN BY COST ACTIVITY

Cost activity	Financial cost per MR and OPV dose delivered	Opportunity cost per MR and OPV dose delivered	Economic cost per MR and OPV dose delivered
Campaign management	$ 0.012 ($0.011–$0.013)	$ 0.047 ($0.046–$0.049)	$ 0.059 ($0.065–$0.069)
Vaccine and Vitamin A and albendazole collection, distribution and storage	$ 0.011 ($0.010–$0.012)	$ 0.022 ($0.020–$0.023)	$ 0.032 ($0.031–$0.034)
Cold chain maintenance	$ 0.002 ($0.001–$0.002)	$ 0.009 ($0.008–$0.010)	$ 0.010 ($0.009–$0.011)
Training	$ 0.063 ($0.061–$0.066)	$ 0.060 ($0.059–$0.062)	$ 0.123 ($0.121–$0.126)
Social mobilization and advocacy	$ 0.041 ($0.038–$0.043)	$ 0.081 ($0.078–$0.084)	$ 0.122 ($0.118–$0.125)
Supervision	$ 0.052 ($0.051–$0.053)	$ 0.035 ($0.032–$0.037)	$ 0.087 ($0.084–$0.089)
Service delivery: facility-based	$ 0.040 ($0.038–$0.041)	$ 0.042 ($0.040–$0.044)	$ 0.082 ($0.079–$0.084)
Service delivery: temporary sites	$ 0.069 ($0.067–$0.071)	$ 0.037 ($0.035–$0.039)	$ 0.106 ($0.103–$0.109)
Service delivery: mobile teams/outreach	$ 0.062 ($0.059–$0.065)	$ 0.035 ($0.033–$0.036)	$ 0.097 ($0.094–$0.100)
Service delivery: sweeping/mop-up	$ 0.007 ($0.006–$0.008)	$ 0.032 ($0.031–$0.034)	$ 0.040 ($0.038–$0.041)
Waste management*	$ 0.004 ($0.004–$0.005)	$ 0.017 ($0.016–$0.019)	$ 0.022 ($0.020–$0.023)
AEFI management	$ 0.002 ($0.002–$0.003)	$ 0.001 ($0.001–$0.002)	$ 0.004 ($0.003–$0.004)
Record-keeping, HMIS, monitoring and evaluation	$ 0.022 ($0.021–$0.022)	$ 0.045 ($0.043–$0.047)	$ 0.067 ($0.065–$0.069)

** Denominator – number of MR doses delivered*

ANNEX V: BREAKDOWN BY RESOURCE TYPE

Resource type	Financial cost per MR and OPV dose delivered	Opportunity cost per MR and OPV dose delivered	Economic cost per MR and OPV dose delivered
Operating cost (by descending financial cost per dose)			
Per diem and travel allowances	$ 0.164 ($0.160–$0.168)	-	$ 0.164 ($0.160–$0.168)
Transport and fuel	$ 0.064 ($0.061–$0.066)	-	$ 0.06 ($0.061–$0.066)
Vaccine injection and safety supplies	$ 0.060 ($0.059–$0.061)	-	$ 0.060 ($0.059–$0.061)
Workshops and meetings	$ 0.021 ($0.020–$0.023)	-	$ 0.021 ($0.020–$0.023)
IEC and other printing costs	$ 0.021 ($0.020–$0.022)	-	$ 0.02 ($0.020–$0.022)
Paid labor	$ 0.021 ($0.020–$0.021)	$ 0.213 ($0.210–$0.216)	$ 0.234 ($0.210–$0.237)
Vehicle maintenance	$ 0.019 ($0.018–$0.021)	-	$ 0.019 ($0.018–$0.021)
Communication	$ 0.006 ($0.006–$0.007)	-	$ 0.006 ($0.006–$0.007)
Cold chain repairs and energy costs	$ 0.002 ($0.002–$0.003)	-	$ 0.002 ($0.002–$0.003)
Stationery and other supplies	$ 0.002 ($0.002–$0.003)	-	$ 0.002 ($0.002–$0.003)
Incinerators (operating)*	$ 0.002 ($0.001–$0.002)	$ 0.001 ($0.001–$0.002)	$ 0.003 ($0.002–$0.003)
Utilities	$ 0.001 ($0.0001–$0.001)	$ 0.004 ($0.003–$0.004)	$ 0.004 ($0.003–$0.005)
Volunteer labor	-	$ 0.218 ($0.213–$0.222)	$ 0.218 ($0.213–$0.222)
Capital cost (by descending economic cost per dose)			
Vehicles	-	$ 0.010 ($0.009–$0.011)	$ 0.010 ($0.009–$0.011)

Buildings	-	$ 0.009 ($0.008–$0.010)	$ 0.009 ($0.008–$0.010)
Incinerators (capital)*	-	$ 0.004 ($0.003–$0.004)	$ 0.004 ($0.003–$0.004)
Cold chain equipment	$ 0.002	$ 0.003 ($0.002–$0.003)	$ 0.005 ($0.004–$0.005)
Other equipment	-	$ 0.0004 ($0.0002–$0.001)	$ 0.0004 ($0.0002–$0.001)

** Denominator – number of MR doses delivered*

ANNEX VI: ORIGINAL AND CALIBRATED SAMPLING WEIGHTS

District	Facility number	Original inverse probability of sampling weights	Inverse probability of sampling weights
Bombali	1	220	8.4
Bombali	2	78	2.1
Bombali	3	220	7.4
Bombali	4	220	5.2
Bonthe	5	2	0.6
Bonthe	6	29	3.0
Bonthe	7	29	2.6
Bonthe	8	2	0.7
Bonthe	9	4	1.0
Bonthe	10	29	3.3
Koinadugu	11	22	2.0
Koinadugu	12	22	2.2
Koinadugu	13	1	0.5
Koinadugu	14	28	2.3
Koinadugu	15	2	0.8
Port Loko	16	186	6.9
Port Loko	17	15	1.4
Port Loko	18	186	7.2
Port Loko	19	84	3.6
Port Loko	20	186	6.9
Port Loko	21	6	0.9
Port Loko	22	15	1.4
Pujehun	23	243	7.5

Pujehun	24	243	6.6
Tonkolili	25	36	3.1
Tonkolili	26	42	2.6
Tonkolili	27	306	9.4
Tonkolili	28	306	9.0