Comparative Pilot Study of Methods for Assessing Routine Vaccine Coverage in Health Districts of the DRC and CAR

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List of Acronyms

EY	Eligibility year
ArcGIS	Geographic Information Software
AVS	Supplementary Immunization Activities
BCG	Bacille de Calmette et Guérin
CCI	Intra-cluster correlation coefficient
DHIS2	Digital Health Information System 2
HZ/HD	Health Zone/Health district
DTC	Diphtheria, tetanus, whooping cough
VCS	Vaccine Coverage Survey
DHS	Demographic and Health Survey
EPS	Effect of sample design
KSPH	School of Public Health, University of Kinshasa
BMGF	Bill & Melinda Gates Foundation
FOSA	Health Facility
GPS	Global Positioning System
ICASEES	Central African Institute for Statistics and Economic and Social Studies
LQAS	Lot Quality Assurance Sampling
MCZ	Health Zone Chief Medical Officer
MICS	Multiple Indicator Cluster Survey
MSP	Ministry of Health and Population

WHO	World Health Organization
PCV	Pneumococcal Conjugate Vaccine
EPI	Expanded Program on Immunization
PPT	Probability Proportional to Size
HIPC	Probability proportional to estimated size
CAR	Central African Republic
DRC	Democratic Republic of Congo
GIS	Geographic Information System
SNIS	National Health Information System
TEE	Effective Sample Size
UCLA	University of California, Los Angeles
UEP	Primary Sampling Unit
UES	Secondary Sampling Unit
UNICEF	United Nations International Children's Emergency Fund
CI	Confidence Interval
EA	Enumeration Areas
WUENIC	WHO/UNICEF Estimates of National Immunization Coverage
HA	Health Area

Forward

His Excellency the Minister of Health and Population of the CAR would like to thank the research team from the Kinshasa School of Public Health (KSPH), the UCLA Fielding School of Public Health research program in the DRC, the Department of Public Health at the University of Bangui and ICASEES, who worked tirelessly to produce the report on the comparative pilot study of vaccination coverage methods in the health districts of the DRC and CAR, supported by funds from the Bill & Melinda Gates Foundation (BMGF). The lessons learned from this study, can guide the choice of vaccine coverage assessment method in the context of countries with limited resources.

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Summary

Vaccine-preventable diseases are significant public health problems in both the Central African Republic (CAR) and the Democratic Republic of Congo (DRC), due to their contribution to infant and child mortality. In order to address vaccine-preventable diseases through public health initiatives, national immunization programs must first evaluate vaccine coverage rates; however, there are many study methodologies for coverage evaluation. When selecting evaluation methods, researchers must consider three major parameters on a country-to-country basis: accuracy, cost and time.

The ideal method for estimating immunization coverage would maximize the number of eligible households or children surveyed, while also minimizing cost and implementation time. The WHO has published guidelines on vaccine coverage surveys (VCS) since 1982. Prior to 2018, these directives consisted of a single "one size fits all" methodology in the form of a cluster survey. However, the 2018 revised manual provides additional context and information on how countries can design a survey that is appropriate and feasible for the context needed – including suggestions for the district of health zone (operational) level. Therefore, alternative evaluation methods should be assessed including those in the recommendations of the 2018 revised WHO VCS manual for their comparability to the original WHO cluster method in terms these same three parameters: accuracy, cost, and time. In this study, the selected alternative methods (some of which are detailed in the 2018 WHO manual) include: the adapted Kinshasa School of Public Health (KSPH) method, Geographic Information System (GIS) method and Lot Quality Assurance Sampling (LQAS) method. This is not meant to be an exhaustive list of alternative methodologies, instead to serve as a basis for exploring how variations in methodologies can affect outcomes in terms of precision, time and cost.

The WHO coverage survey manual has been published for over 4 decades, and there have been a number of surveys which have used various versions of the WHO methodology. Most recently Pakistan carried out a large survey using the 2018 revised WHO methodology in over 100 districts in (1, 2), and Burkina Faso has also successfully carried out surveys following guidance in the WHO VCS manual since 2018 (3). However, the unique challenges of the DRC (over 500 districts/health zones) and CAR (high insecurity) have limited adoption of the WHO VCS, however, with modifications these methods are becoming more adaptable to individual country's needs. The present study was conducted to compare four vaccine coverage assessment methods (from the perspective of the assessment providers) at the health zone/health district level in two different countries.

Sampling for all assessments included children aged 6 to 23 months in households in five health zones (HZ)/health districts (HD) selected for this pilot study, two in DRC and three in CAR. Vaccine coverage data were collected using electronic tablets and transferred to a secure virtual server before being cleaned, processed, and analyzed. Analyses were adapted from WHO

Vaccination coverage quality indicators (VCQI) tools, and data relating to the costs, time and experience of the interviewers were also collected.

All four methods were successfully implemented in both countries in both urban and rural settings. Secondly vaccine coverage estimates were calculated with confidence intervals (CI) at the HZ/HD level for each method. At the HZ/HD level, there was some variation in the point estimates, but typically CIs for each method overlapped; for example, estimates for complete vaccination coverage in the Bangui HD ranged from 43.8% (KSPH) to 52.2% (LQAS). As expected, the CIs generated by the WHO method were smaller and accounted for more variance as the number of clusters was significantly greater (41) than the other methods (10/5). However, these differences in uncertainty (interpreted as the CI width) overlapped, additional statistical analysis including logistic regression will be completed at a later time.[1] Typically, national and sub-national surveys of vaccination coverage are generally designed with a margin of error of 5-10%.

The WHO method took the longest and was the most expensive to implement (but had the smallest CI widths and was considered the most accurate in terms of vaccine coverage estimates. The per district cost ranged from $10,898 (when excluding coordination costs and adjusted for actual labor) to $60,012, as implemented. At the cluster level, the WHO method was the least expensive as 41 clusters were included per health zone, with per cluster costs ranging from $266 (when excluding coordination costs and adjusted for actual labor) to $1464, as implemented. The LQAS method was the quickest method to implement, requiring the fewest team members, and was the least expensive with an average cost. However, at the HZ/HD level, LQAS estimates often had the widest confidence intervals – indicating greater uncertainty in the point estimate. The KSPH and GIS methods required almost the same amount of time in terms of workload and staffing and were approximately the same cost to implement ranging between $10,852 (when coordination costs are removed and person-time costs are adjusted for actual labor) and $23,757 (method as implemented), with coverage estimates varying according to location. The GIS method required additional work at the management level to produce the maps, generate weights for each buffer point, and preselect sites; yet, this helped limit selection bias by interviewers in the field. However, when implementation of GIS cluster selection was not done correctly in practice (GPS points indicating that buffer zones were not accurately reached), it was very difficult to apply appropriate weighting schemes during analysis – leading to the GIS method to have the least overlap coverage with the other 3 methods. This report will present coverage findings overall and by vaccine, cost and time estimates, qualitative findings from teams conducting each method, and simulations on variations of cluster selected. We also present experiences from the data collection teams and the coordination team on methodology implementation. These quantitative and qualitative data highlight strengths and limitations including suggestions for training, implementation and data analysis which should be considered for future studies.

[1] This report will be updated as additional analysis are completed. General findings are considered final.

This study suggests that the different vaccine coverage assessment methods compared are valid and feasible with limitations which should be contextualized in the planning of a national coverage surveys. Many of the coverage point estimates were not different (overlapping confidence intervals, significance testing for p-values for tests of differences will be completed later), although some had more variation than others depending on the context of implementation. Additionally, we present differences in cost and time between methods. Overall, the findings suggest that the choice of vaccine coverage survey method to be used in a country depends on the context, availability of population and geographic data, and at which level of the health system estimates are needed. Further, when using the revised WHO manual and adapting the methods as we have done, can help provide context for VCS. This choice of methodology is also ultimately a trade-off between cost and time and level of precision – the most precise estimates were generated by the most expensive and time-consuming WHO-cluster method. We suggest that while estimates with their CIs may be sought at the HZ/HD level for ensuring children from every district/health zone are includes in surveys and potentially providing some information on operational outcomes, many of the methods presented may lack the statistical strength to provide an unbiased estimate at the operational level, and coverage results may be most appropriately presented at the provincial/regional level.

1. Context

The World Health Organization (WHO) considers vaccination to be a proven intervention for controlling and eliminating deadly infectious diseases. It is estimated that vaccination prevents between 3.5 and 5 million deaths every year from diseases such as diphtheria, tetanus, whooping cough, influenza and measles (4). Vaccination is an incredibly cost-effective investment: an effective public health strategy, accessible to even the most hard-to-reach and vulnerable populations worldwide (4). The WHO has set a vaccination coverage target of 90% for essential vaccines administered during childhood and adolescence in member countries by 2030 (5).

Immunization coverage is an important indicator for monitoring immunization trends and guiding national, regional and international policies to achieve the WHO's 2030 coverage targets. Measuring immunization coverage based on administrative data in most low- and middle-income countries results in erroneous figures that may not reflect actual coverage. These discrepancies in reported estimates can be attributed to a number of problems: the use of a denominator, or population estimate, derived from out-of-date, inaccurate and incomplete censuses, errors in the recording of vaccinations in health facilities, and errors in data tallying and data transmission between health systems (6, 7). The last population censuses carried out in the Democratic Republic of Congo (DRC) and the Central African Republic (CAR) date back to 1984 (8) and 2003 (9), respectively. Moreover, with the instability created by politico-military conflicts, loss of life and forced population displacements, these two countries have undergone significant demographic changes since the last official census. Cluster epidemiological surveys can also compensate for the weaknesses of national census administrative reports. This approach is easier to implement than simple random census sampling, as fieldwork is concentrated on a fixed number of clusters and a limited geographical area (10).

In the DRC and CAR, large-scale surveys such as the Demographic and Health Survey (DHS) and the Multiple Indicator Cluster Survey (MICS) are carried out every 3 to 6 years, using highly standardized probabilistic statistical methods (11, 12). In addition, the international partners supporting the DRC and CAR generally provide substantial technical assistance and quality control for the design, implementation, analysis and reporting of these surveys. However, the results of DHS and MICS are not immediate and may not be effective tools for assessing rapidly changing populations if they are only carried out every 3 to 6 years. Thus, rapid and cost-effective annual surveys at Health Zone or Health District level can help improve programmatic decision-making and serve as an alternative assessment method.

In 2018, WHO revised its method for assessing immunization coverage. The previous method relied on drawing a sample of 210 children in 30 clusters to achieve a quota of seven children per cluster and had many challenges. In particular, the inferences drawn from the results of this method were erroneous, as quota sampling is not probability sampling (13). The WHO vaccine coverage assessment method, considered the gold standard, uses either a one-stage or two-stage cluster sampling design. In the former, clusters are sampled and then a full census is carried out in the selected clusters, while in the latter, a second sampling is carried out at the second stage rather than a census (10, 13). While the 2018 revised WHO guidelines include a number of tools to aid countries in designing the most appropriate method for specific contexts, the cluster method specifically requires a large number of small clusters, which can carry an exorbitant cost (10).

Since 2018, the DRC has been conducting an annual immunization coverage survey using the WHO method with modifications to the second sampling stage (KSPH). In this modified method, clusters are determined as Health Areas corresponding to neighborhoods in urban areas and sectors in rural areas. In each cluster, instead of a full census, 30% of the avenues (if urban) or villages (if rural) are randomly selected according to the cluster's environment. Households in these specific avenues or villages are then systematically selected (14). The most recent survey (2023) was carried out in all of the DRC's 26 provinces and 519 health zones (HZ), at a cost of USD 1,800,000. The entire process, from protocol design to dissemination of results, took six months. The result of this survey was a general coverage estimate for the health zone (operational level), with wider confidence intervals, and an aggregated provincial estimate based on all clusters. This aggregated provincial estimate includes more clusters than the WHO standard method and helped to ensure that all health zones were represented.

The CAR authorities plan to organize their first immunization coverage survey this year. To date, the only epidemiological data used in the country on vaccination coverage are those produced by the Central African Institute for Statistics and Economic and Social Studies (ICASEES) from the 2018 MICS-RCA-6 survey (15).

As in previous DRC and CAR immunization surveys, reported immunization coverage in these countries is below the WHO programmatic threshold. Among children aged 12 to 23 months, 41.5% in DRC (14) and 4.5% in CAR (15) are considered fully vaccinated according to WHO standards. This "fully vaccinated" status is determined both by possession of the vaccination card and by the mother/guardian’s recall.

Given that the WHO's basic coverage assessment method can be complex to implement at a sub-national level, such as the health zone or district level, the creation of a toolbox of additional standardized survey methods (some of which are outlines in the 2018 revised WHO coverage survey guidelines) could enable countries to choose the method that best suits their programmatic needs and available resources. With this in mind, the estimated vaccine coverage in 5 clusters (Health Areas) per HZ/HD can give an idea of HZ/HD operations. At the HZ/HD level, we assumed greater population homogeneity based on similar socio-cultural characteristics and consider this to be the operational level for local deployment of services. Several other survey methods for assessing vaccination coverage have been described but have not been standardized. These could include: the Lot Quality Assurance Sampling (LQAS) method (16, 17), and the compact segment, grid-based geographic information system (GIS) sampling method (18, 19).

All proposed alternative survey methods have advantages and disadvantages. The LQAS method, for example, groups geographical areas or "batches" according to whether they have acceptable or unacceptable coverage, on the basis of a small random sample. This method determines the quality of a batch ("acceptable" or not) by studying the vaccine coverage of a small sample taken at random from the batch. This determination of batch coverage depends on an established upper threshold (target vaccine coverage) and a lower threshold (minimum number for acceptable coverage). One of the advantages of this statistical sampling method is the ability to flag variations in coverage and areas of low coverage among batches, unlike an independent check such as that carried out after mass vaccination campaigns. Variations of this method have been tested, with adjustments such as dividing the sample into smaller groups to increase efficiency and using multiple classification thresholds to identify strengths and weaknesses (17, 20, 21).

Alternatively, in surveys using compact segment sampling, clusters are selected with probability proportional to size (PPS). After sampling, each selected cluster and its individual dwellings are mapped. The clusters are divided into relatively equal segments, and a single segment is then drawn at random from each cluster for monitoring. All households in the randomly selected segment are interviewed, and seven households from the target population are then included in the sample (12-14).

In the grid-based Geographic Information System (GIS) sampling method, clusters can be selected using stratified random sampling within each health district selected from satellite imagery habitat feature layers. Within each of the units selected by GIS, areas are randomly selected, each with population estimate proportional to the area of the chosen site. This random selection process is carried out using the "Create Random Point" tool in the ArcGIS package, or other statistical software such as R. This tool ensures that the points generated have a minimum separation distance, which can be set according to whether the area is urban or rural, and which must be set so that no unit is sampled twice. This method can also be used to select units on mesh layers, based on population and other layered data. GPS points or gridded units are generated and selected at random, followed by the generation of an enumeration area polygon around each point to include the approximate number of households sufficient to capture the target population per cluster. All households within the polygon (the enumeration area) are given the opportunity to be interviewed until the required sample size is reached. Once this target has been reached, the survey stops at the GPS point polygon (19). There are also a number of variants for this type of methodology, which could be implemented depending on the completeness of cartographic data in the country or area to be surveyed.

These different vaccine coverage assessment methods have been used to assess vaccine coverage in previous studies, where they were compared either with each other or with the traditional EPI vaccine coverage assessment method (22, 23). Although previous studies have encouraged the use of alternative methods to assess vaccine coverage, these methods have not yet been standardized for widespread use.

To be standardized as alternative assessment methods to the 2018 WHO cluster sampling assessment method, these methods must be compared to the latter in terms of effectiveness, cost, time and ease of implementation. All proposed alternatives must also be implemented to compare the results of the same population with those of the reference method. To our knowledge, no study has ever been carried out at the same time and in the same place to assess the comparability and standardization of these alternative approaches in an African context. An evaluation comparing three survey methods was recently carried out in Pakistan and revealed that estimates were similar between the alternative methods and the traditional EPI cluster survey. The alternative methods may have helped reduce selection bias but require a larger sample size (18).

The present study is a pilot study that aims to apply each method (LQAS, GIS, KSPH) to assess immunization coverage at the same time and place, to explore how they can be adapted to the context of low- and middle-income countries, and which results are comparable to the WHO standard method. After comparison, successful alternative methods could be suggested for adoption for inclusion in the WHO standard method as alternatives where country resources or needs may vary. This is a Bill & Melinda Gate Foundation (BMGF) funded project to assess innovative methods for rapid assessment of immunization coverage. This project is part of a collaborative effort between the University of California, Los Angeles (UCLA), the Kinshasa University School of Public Health (KSPH) and the DRC Ministry of Public Health, Hygiene and Prevention, the EPI of the DRC and the CAR, the Ministry of Health and Population of the CAR, the Department of Public Health of the University of Bangui in the CAR, ICASEES/RCA, WHO and the United Nations Children's Fund (UNICEF).

2. Research Questions

This study aimed to answer the following research questions:

- ✓ Is there any evidence that the vaccine coverage estimated by each of the three methods is close to that estimated by the WHO standard method [accuracy]?
- ✓ How do the time and logistics involved in implementing alternative vaccine coverage surveys compare with the WHO standard method [time]?
- ✓ How does the cost of each alternative method compare with that of the WHO standard method [cost]?

Next, the study aimed to assess the performance of Health Zones (HZ)/Health Districts (HD) in relation to vaccination coverage for each method:

- ✓ What is the proportion of children aged 12 to 23 months who have been fully vaccinated in the HZ/HD selected according to the vaccination schedule of two countries (DRC and CAR)?

- ✓ What is the proportion of children aged 6 to11 months who have been vaccinated in the selected HZ/HD according to the vaccination schedule of two countries?

- ✓ What is the proportion of children aged 12 to 23 months who have received no vaccine (zero dose) in the selected SDAs/SSAs of two countries?

- ✓ What is the proportion of children aged 12 to 23 months who have dropped out of vaccination in the selected HZ/HD?

- ✓ What are the reasons associated with incomplete vaccination and non-vaccination of children aged 12 to 23 months in the selected SDAs/SDs of two countries?

3. Objectives

3.1. *General Objective*

The overall aim of the Innovation in Rapid Vaccine Coverage Surveys study is to compare the estimation of vaccine coverage by the Lot Quality Assurance Sampling (LQAS) method, the WHO method modified by KSPH, the sampling method using the Grid Geographic Information System (GIS) with that of the WHO cluster method revised in 2018 in terms of accuracy, cost and time.

3.2. *Specific Objectives*

The study of innovation in rapid vaccine coverage surveys focused on the following specific objectives:

1. Estimate the performance indicators of infant immunization services in the HZ/HDs of two countries:

   i. Determine the proportion of vaccination card/booklet holders;

   ii. Proportion of children aged 12 to 23 months fully vaccinated in HZ/HD;

   iii. The proportion of children aged 12 to 23 months who have received the required number of doses of vaccine for each antigen recommended by the immunization schedule in the HZ/ HD;

iv. Drop-out rate per antigen for multidose vaccines;

v. The proportion of children aged 12 to 23 months who have received no dose of vaccine for each antigen recommended by the immunization schedule in the HZ/ HD;

vi. The proportion of children aged 6 to 11 months vaccinated in HZ/HD according to the vaccination schedule of two countries.

2. Identify the reasons for non-vaccination or incomplete vaccination of children aged 12 to 23 months.

3. Calculate the average time needed to estimate vaccine coverage for the different vaccine coverage survey methods.

4. Run simulations on the variation/range of the number of selected clusters to determine the extent of the observed variation and whether the optimal number of clusters can be estimated.

5. Calculate the average cost of estimating vaccine coverage for the different methods.

6. Determine the difference between the three methods of estimating vaccine coverage described in the literature and the WHO standard method in terms of effectiveness, cost and time.

7. Formulate recommendations that could lead to the adoption and standardization of alternative methods for estimating vaccine coverage in the context of middle- and low-income countries.

4. Methods

4.1. Type of Study

This was a cross-sectional analytical study aimed at estimating vaccination coverage primarily in children aged 12 to 23 months, and secondarily in those aged 6 to 11 months. In addition, the study compared methods for estimating vaccine coverage in terms of accuracy, cost and time.

4.2. Study Framework

The survey was carried out simultaneously in five HZ/HD in four provinces/regions: two in DRC and three in CAR. In the DRC, the ZSs were selected in the province of Kinshasa (urban HZ: N'djili) and in the province of Kwango (rural HZ: Boko). In CAR, one Health District (HD) was selected in Region 7, the urban HD of Bangui II, and the other two in Health Region I: the HD of Begoua (semi-urban) and Bossembele (rural). The table below shows the current demographic profile of the five HD/HZ selected (Table 1).

Table 1: Demographic situation of DRC and CAR heath zone/health districts selected for the Innovation study in Rapid Vaccine Coverage Surveys in 2022

Country	Province/ Region	HZ/HD	Pop. 2022	Live Births	Survivors	6-11 months	12-23 months
Proportion				**4.00%**	**3.60%**	**1.75%**	**2.90%**
DRC	Kwango	Boko	260,542	10,422	9,380	4,560	7,556
	Kinshasa	N'djili	204,532	8,182	7,364	3,580	5,932
Proportion				**3.50%**	**3.04%**	**1.75%**	**2.90%**
RCA	R7	Bangui II	172,950	6,053	5,258	3,027	5,016
	R1	Begoua	330,623	11,572	100,551	5,786	9,588
	R1	Bossembele	213,541	7,474	6,492	3,737	6,193

4.3. Sampling

Study Population

The vaccine coverage survey included children aged 6 to 23 months.

Sample Size Estimation

WHO Cluster Method (WHO)

Sample size was estimated according to WHO recommendations for calculating cluster sample size when estimating vaccine coverage.

→ Number of strata covered by the survey (**A**) = 5 (5 Health Zones/Health Districts including 2 in DRC and 3 in CAR as explained above).

→ Effective sample size (TEE) (**B**) = 103 households per HZ/HD

TEE is calculated using the formula below:

$$n \geq \frac{kZ^2_{\left(1-\frac{\alpha}{2}\right)}}{4d^2} + \frac{1}{d} - 2Z^2_{\left(1-\frac{\alpha}{2}\right)} + \frac{Z_{\left(1-\frac{\alpha}{2}\right)} + 2}{k}$$

The meaning of the parameters used in the formula was as follows:

$Z_{(1-a/2)}$ = standard normal distribution evaluated at 1 - x (1.96)

α = significance level

d = desired half-width of the confidence interval (= 0.10) ;

k = 1 for an expected proportion (p) of fully vaccinated children aged 12 to 23 months of 41.5%, since p is between 30 and 70 percent ($0.3 \leq p \leq 0.7$).

→ Sample design effect (PSE) (**C**): 4 (For an intra-cluster correlation coefficient (ICC) of 0.333 in accordance with the reference manual and 10 households per cluster). It should be noted that this design effect was not far from that calculated for the ECV2021 survey in the DRC, i.e. 3.88 for fully vaccinated children.

→ Average number of households to visit to find an eligible child (**D**): 5 (This number was calculated according to the WHO reference manual using as parameters: EY=1 (year of eligibility in a cohort of children aged 12 to 23 months), birth rate (42.4‰), infant mortality (43 ‰), average household size (5.2 children) (10).

→ Inflation factor to account for non-response and children aged 6-11 months (**E**): according to the vaccine coverage survey carried out in the DRC in 2021, 15% of households have been added to the size to take account of non-responses, giving an inflation rate of 1.18 according to table E of the WHO reference manual on vaccine coverage surveys (10).

The minimum target size (the number of 6-23 month-old children surveyed at the HZ/HD level or effective sample size) was calculated by taking the vaccine coverage reported by the VCS 2021 as the expected coverage for both countries, given that the vaccine coverage of fully vaccinated children in CAR was too low (4,5%) (15). The design effect for ten respondents per cluster (enumeration area) was set at 4, with an intra-cluster correlation coefficient of 0.333 (10). The confidence coefficient was set at 95%, and the degree of precision at 10%. The minimum sample size obtained was increased by 15% to account for children aged 6 to 11 months and non-responses (Table 2).

Table 2: Parameters used for WHO sample size calculations.

Parameters	Value
Number of strata (A)	**5.00**
Expected threshold	0.42
Accuracy required	0.10
Alpha (α)	0.05
$Z_{(1-\alpha/2)}$	1.96
Beta (β)	0.20
Power $(Z)_{(1-\beta)}$	0.84
TEE (B)	103.00
Minimum number of respondents per cluster (c)	**10**
CCI	0.33
EPS or Deff (C)	**4.00**
Number of households to find an eligible child (D)	5.00
Non-response rate (%)	0.15
Non-response inflation rate (E)	1.18
Total number of complete interviews required (Nec) (n)	**2050**
Number of households to be visited	12300
Number of households to be visited by stratum (HZ/HD)* (number of households per stratum)	2460
Number of clusters by strata (HZ/HD)	**41**
Number of households per cluster	60
Total number of clusters	**205**

In summary, for reasons of convenience, the number of full interviews required was reduced to 410 per HZ/HD, making a total of 2050 for all five HZ/HDs. Enumeration Areas (EA) were considered as clusters in this approach. EAs had an average size of 60 households to visit, and for each HZ/HD, 41 EAs were planned, making a total of 205 clusters for all 5 districts. In each EA, more or less ten respondents were interviewed. Each team had to visit 60 households in each cluster in order to have at least 10 respondents, making a total of 2,460 households to be visited per HZ/HD.

WHO Adapted by the Kinshasa School of Public Health (KSPH)

Sample size was estimated according to the WHO procedure for calculating cluster sample size for vaccine coverage estimation.

→ Number of strata covered by the survey (**A**) = 5(Health zone or health district)

→ Effective sample size (**B**): 103 per HZ

→ Design effect (EPS): 1.5

→ Average number of households visited to find an eligible child (**D**): 5

→ Inflation factor to account for non-responses and children aged 6 to 11 months) (**E**):10 %

The minimum target size, the number of children aged 6-23 months surveyed at the level of the health zone or health district in CAR (effective sample size), was calculated by taking the coverage estimates found in the VCS-DRC-2021 as the expected coverage. Assuming that cluster heterogeneity in relation to vaccine coverage within the same health zone or health district is minimal, a cluster effect of 1.5 is applied. The confidence coefficient is set at 95%, and the degree of precision at 10%. The minimum sample size obtained was increased by 10% to account for children aged 6 to 11 months and non-responses. The number of children surveyed per cluster (health area) was obtained by dividing the sample size of the HZ or HD by 10, which is the constant number of health areas to be randomly selected in each HZ or HD. In past VCS, the number of clusters drawn in each Health Zone was set at 5. In this pilot study, this number was increased to 10 clusters to allow simulations to be run to demonstrate the variation in the precision of the estimates as a function of the number of clusters. This allowed us to understand whether our assumptions about homogeneity at health zone level were correct and could help guide the survey in CAR. This number is fixed for practical reasons, linked on the one hand to the average daily number of 9 to 10 children to be covered per interviewer, to the average number of 16 days of data collection, and on the other hand to the financial resources allocated to the survey for all the HZ/HD selected.

It should be noted that in this study we had 10 clusters per HZ/HD, which increased the sample size to 360 children aged 6 to 23 months per HZ/HD and 1440 children for the 4 HZ/HD plus 180 children in the Begoua HD, where the number of children was reduced by half for technical reasons.

Grid-based GIS Method (GIS)

For the sampling method using grid-based GIS, the following formula was used to calculate the sample size:

$$n \geq \frac{kZ^2_{\left(1-\frac{\alpha}{2}\right)}}{4d^2} + \frac{1}{d} - 2Z^2_{\left(1-\frac{\alpha}{2}\right)} + \frac{Z_{\left(1-\frac{\alpha}{2}\right)} + 2}{k}$$

Sample size was estimated according to the WHO procedure for calculating cluster sample size for vaccine coverage estimation.

→ Number of strata covered by the survey (**A**) = 5 (Health zone or Health district)

→ Effective sample size (**B**): 103 per HZ

→ Design effect (EPS): 1.5

→ Average number of households visited to find an eligible child (**D**): 5

→ Inflation factor to account for non-responses and children aged 6 to 11 months (**E**): 10 %

The assumptions for the GIS method were the same as described by the WHO-KSPH method. In past VCSs, the number of clusters drawn in each Health Zone was set at 5; in this pilot study, this number was increased to 10 clusters to enable simulations to be run to demonstrate the variation in precision of estimates as a function of the number of clusters in 4 HZ/HDs and 5 for the Begoua HD for technical reasons. Thus, the calculated sample size was 360 children aged 6 to 23 months per HZ/HD and 1440 children for the 4 HZ/HD and 180 children in Begoua HD.

Lot Quality Assurance Sampling (LQAS)

For the sampling method using lot quality assurance surveys, the sample size was calculated using the following formula(16):

$$n \geq \frac{Z^2_{\left(1-\frac{\alpha}{2}\right)} p(1-p)}{d^2}$$

- $Z_{(1-a/2)}$ = Confidence coefficient for a 95% confidence level (1.96)
- d = degree of precision (= 0.10);

- p = Expected threshold of fully vaccinated children aged 12 to 23 months. According to the latest vaccine coverage survey conducted in the DRC in 2021, this proportion is 41.5%.

- 1-p = proportion of children aged 12 to 23 months not fully vaccinated (100-41.5=58.5%)

- n ≥ 94 households for each HZ/HD, giving an overall sample of 470 households for the five HZ/HD. For reasons of convenience, the size was reduced to 95 households per health district in order to have a whole number in each stratum; this gave a total of 475 households to draw for the five districts.

- This size was divided by the number of health areas in each HZ/HD to find the number of households per health area, considered here as a cluster.

- A decision rule has been specified to classify coverage within the health area. The decision rule depends on two types of error: wrongly classifying coverage as below a threshold when it is equal to or above that threshold (type I), and wrongly classifying coverage as equal to or above a threshold when it is below that threshold (type II).

- This rule was used to classify coverage at the 80% thresholds (the WHO target threshold for immunization coverage at the HZ/HD level), while keeping the risk of alpha and beta errors below 10%. Results were aggregated across health areas to calculate a weighted estimate of coverage for the whole HZ/HD, accounting for the stratified design of the survey.

Sampling Technique

WHO Cluster Method

In the sampling approach, each HZ/HD was considered as a study area. Within each HZ, enumeration areas from the 1984 census, updated to 2010 for the DRC, and the 2003 census, updated to 2022 with census mapping in CAR, formed clusters (10). The primary sampling unit (PSU) was considered the cluster. Sampling was carried out as follows:

→ 1st degree (PSU): in each HZ/HD, 41 clusters were systematically selected within each cluster. If the number of households per cluster was not known, it was calculated by dividing the total cluster population by the average household size. Each cluster was expected to have 60 households. If the clusters were large, they were further segmented so as to have segments with an average size of 60 households. A single segment was drawn at random;

→ 2nd degree (UES): in each selected cluster or segment, all households were enumerated so that 10 households with a child aged 6 to 23 months were systematically drawn. So, to have ten households with at least one eligible child, the field teams visited sixty households per cluster. A minimum of 10 respondents per cluster was expected, making a total of 410 complete interviews required per HZ/HD (Figure 1).

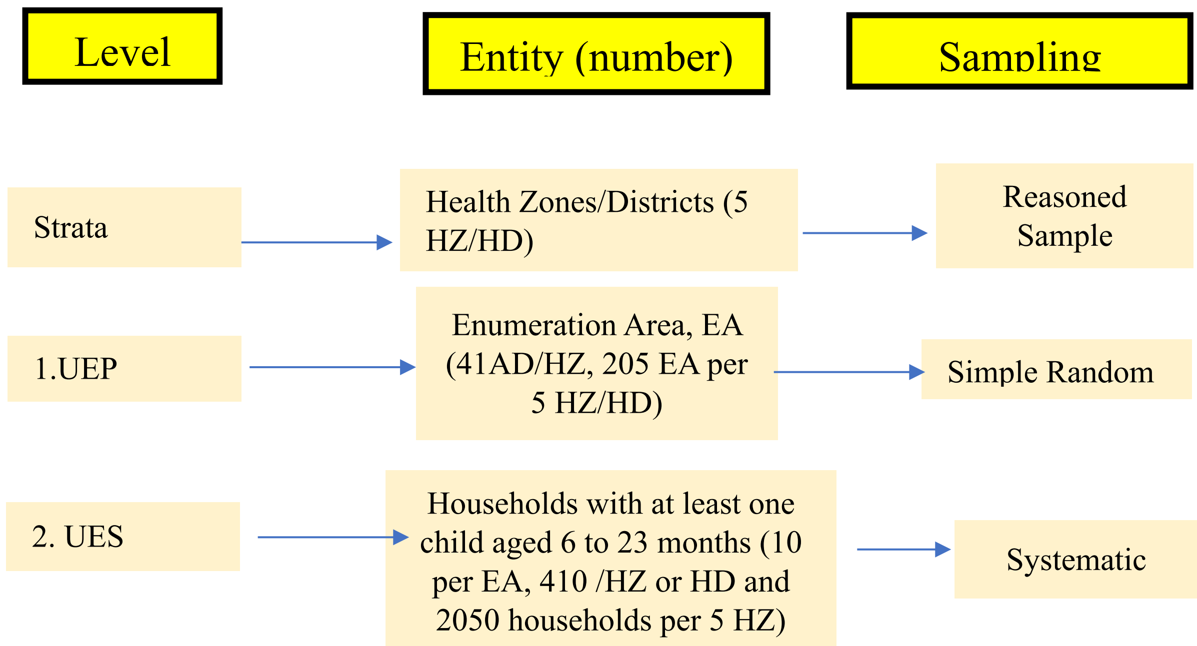

Figure 1. Sampling Strategy for each level of the WHO Method

Data relating to EA were obtained from the national statistics programs in both countries.

The field team was equipped with plot survey sheets for household enumeration. The plot sheet indicates the main road in the avenue or village, as well as characteristic physical features such as schools, churches and other landmarks. Households with children aged between 6 and 23 months were included in the enumeration. The plot survey was carried out in blocks according to the configuration of the village or avenue. The blocks were separated by the main road running through the village/venue. The plot surveys drawn up for each village/venue in an AD were grouped together to form the sampling frame. From this sampling frame, enumeration was carried out with the help of community relays living in the villages or streets concerned. For each cluster, a map of these sites was drawn up for comparison with that obtained from household data. All data collection teams were trained in this sampling method. The sampling frames thus constituted were transmitted to the Supervisor, who in turn brought them back to the Coordination Team at central level.

In selected households with children aged 6 to 23 months, the interviewer conducted an interview with the child's mother/caregiver. All eligible children in a household were included in the interview.

WHO Method Modified by the Kinshasa School of Public Health (KSPH)

In this method, clusters are selected using three-stage probability sampling. The study used a sampling frame from the list of health areas taken from the National Health Information System (DHIS2) data base. The frame lists all the HZ/HD in the two countries with their respective health areas. This sampling frame was obtained using the DHIS2 application.

In the survey approach, each HZ/HD was considered as a study area.

In each HZ/HD, the health areas (HA) formed clusters. The primary sampling unit (PSU) is the cluster. Sampling was carried out at three levels:

- First level (UEP): in each health zone, 10 clusters were selected at random from the exhaustive list of H; if the HZ/HD had no more than 10 health areas, all were selected.

- Second level (UES): In each selected HA, six (6) segments of 16 containing the avenues/villages were selected at random from geographical subdivisions of the health area based on satellite images (if available) or a map

- Third level (UET): in each of the 6 selected segments of the health area, households in the segment make up the sampling frame. A plot survey was carried out until a total of 18 eligible households were found in each segment, of which 5 eligible households were selected by a systematic random draw, totaling at least 30 households per health area, with at least 36 eligible children 6-23 months (Figure 2).

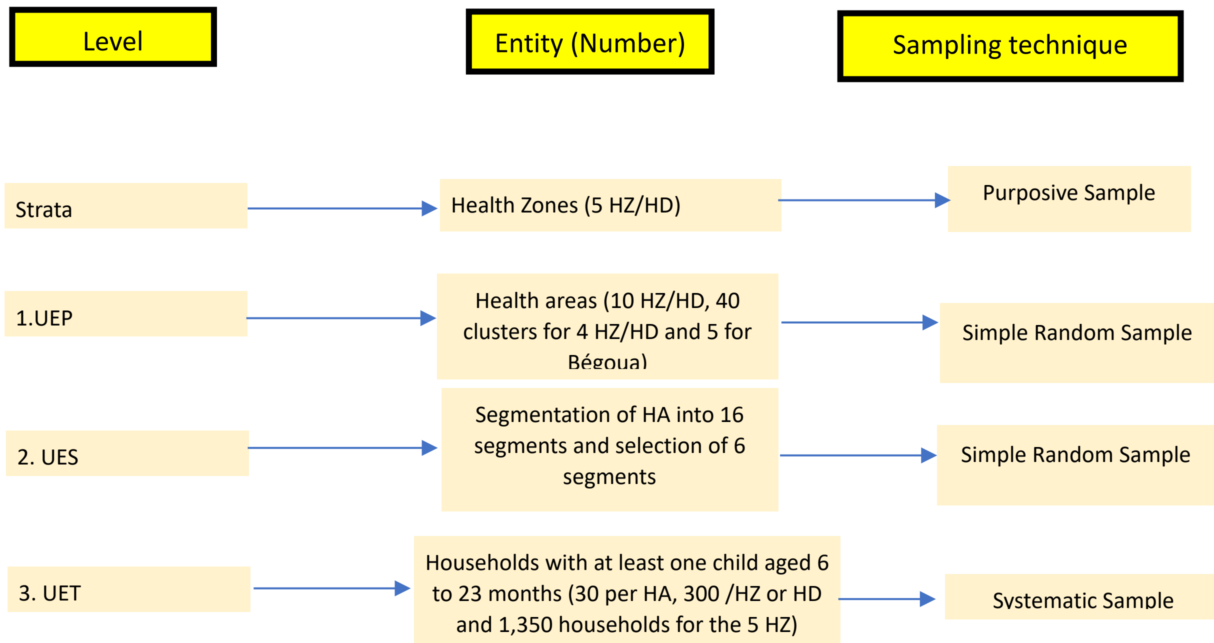

Figure 2. Sampling procedure at different levels for the WHO-KSPH method

The simple random selection of health areas was carried out centrally by the research team. A random number generator was used to select ten health areas out of the total number of health areas in each of the 4 HZ/HD and five health areas in the Begoua HD for technical reasons. The research team also selected two replacement health areas for each HZ/HD, to be used in the event of accessibility problems. All health areas had an equal chance of being selected and accessible. If team safety could not be guaranteed, the first of the health areas on the reserve list was used directly to replace the insecure health area, and the study coordination team was notified of this decision by the supervisor and the survey team concerned.

Data relating to the villages or avenues of the health areas were collected at the HZ/HD level and from the political-administrative and health authorities (nurse) at the local health area level. These authorities have annually updated lists of all villages and avenues by health area. Team leaders drew random samples of health units from these lists. However, the maps available at central level were used to sample segments in health areas for which satellite images were not available.

In urban areas, supervisors visited neighborhood offices to obtain a map of the HA and an exhaustive list of avenues. In rural areas, supervisors visited sector and health center offices to obtain a map of the health area and an exhaustive list of villages.

Using the available map, the team drew three vertical and three horizontal parallel lines, equidistant from each other and starting from the center of the map, so as to divide the health area into 16 segments, numbered from 1 to 16, starting from top to bottom and from left to right. Of these 16 segments, 6 were pre-selected by coordination (Figure 3). A large part of this segmentation was carried out by the coordination team and based on existing maps. The research team conferred with local authorities to identify and delimit the selected segments, particularly in terms of avenues in urban areas or villages in rural areas. Once all or part of the avenues or villages had been identified, the research team carried out a household parcel survey to identify 18 eligible households per segment, using a parcel survey form.

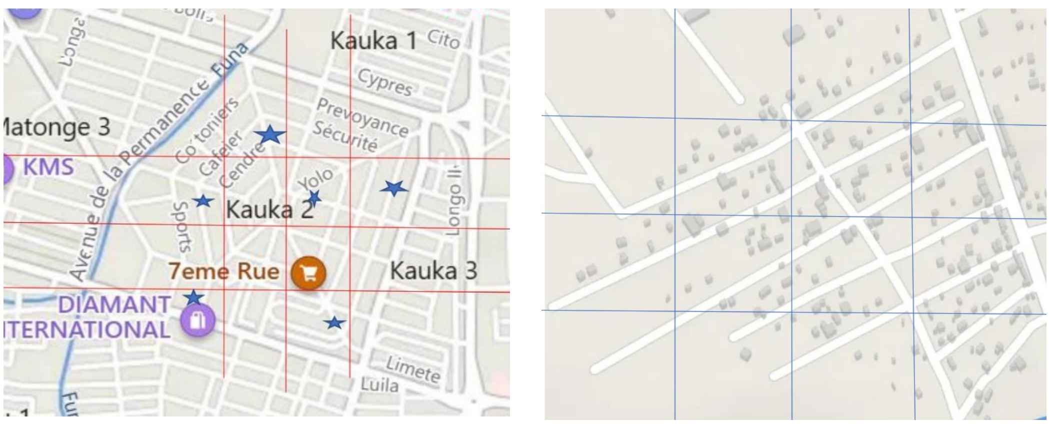

Figure 3: Examples of how to divide an urban health area and a rural health area into 16 segments, and an indication of the pre-selected segments.

Once the plot survey was carried out, the research team selected five (5) households in each segment by systemic drawing, to ultimately include 30 households per health area and 300 per health zone, with an expected 360 children aged 6 to 23 months in these 30 households. In the Begoua Health District, this figure was halved for technical reasons.

The field team was provided with plot sheets to enable them to count households. The plot survey sheet indicates the village's main road, as well as characteristic physical features such as schools, churches and other landforms. Households with children aged between 6 and 23 months were included in the enumeration. The plot survey was carried out in blocks according to the configuration of the village or avenue. The blocks were separated by the main road running through the village/venue. The plot surveys drawn up for each village/venue in a health area were grouped together to form the sampling frame. Based on this sampling frame, enumeration was carried out with the help of community relays and local guides living in the villages or avenues concerned. The enumeration carried out on the basis of the plot survey was recorded in the tablet for each segment of the Health Area (number of households surveyed, number of eligible households) to generate the weightings. All data collection teams were trained in this sampling method. The sampling frames were then sent to the supervisor, who in turn returned them to the coordinator. In households with children aged 6 to 23 months, the interviewer interviewed the head of the household and the mother/guardian of the child aged 6 to 23 months. All eligible persons in the household were interviewed.

Grid-based GIS Method – KSPH Modified (GIS)

The Geographic Information System (GIS)-based approach uses a gridded demographic dataset (GDD) as the main data set. The GDD estimates population density using high-resolution satellite imagery coupled with existing demographic datasets, which may include population estimates from the latest available census. In this study, we used either the Adjusted Population Density v4.11 dataset from the United Nations World Population Project, or datasets from GRID3, which provides extractions of settlement features with population estimates. In order to optimize settlement detection in rural areas where satellite-derived GDDs may not be very accurate due to the emergence of new settlements (which may not be captured if the satellite imagery used is a few years old), the most recent Village Coordinates (VC) dataset was used as additional inputs for feature extraction. The implementation of this approach was programmed in R and adapted to other GIS-based analysis software such as ArcGIS. In the sampling approach, each HZ/HD was considered as the study area. The primary sampling unit (PSU) consisted of the Enumeration Areas (EA) obtained after GDD and VC processing. Sampling was carried out as follows: First, without a feature extraction dataset, a grid of 1 km2 spatial resolution corresponding to the extension of each HZ/HD was created. Then, based on the GDD used and the settlements' degree of urbanization classification (22), the grid cells were grouped into two types of sampling clusters: urban clusters (towns and villages) and rural clusters (villages and hamlets). VCs were previously added to cluster generation to improve the accuracy of GDDs and feature extraction datasets. This process was not important when the feature extraction datasets were available, as they contained all this information.

A total of ten points were randomly generated using R within the clusters (polygons) created. The proportion of points in urban and rural clusters was defined according to the size (number of inhabitants) of each cluster. Within a given cluster - urban, for example - each grid cell had an equal probability of being selected after being weighted by its number of inhabitants (sampling proportional to size). It is important to note that random points were constrained to a minimum separation distance of 100 m in urban clusters and 1 km in rural clusters, to avoid accidentally sampling the same establishments. Around each selected random point, a buffer circle with a radius of 100 m in urban clusters and a radius of 500 m in rural clusters was created and assigned to an EA or PSU. Lists with back-up random points (two per HZ/HD per cluster) were provided in case the facility with the selected site no longer existed or was considered unsafe.

In each EA, interviewers were trained to collect data until the expected number of eligible households (36 households with a child aged between 6 and 23 months) had been covered. Each household in the EA had an equal chance of being selected. If the 36 households were not reached in a given EA, interviewers were allowed to navigate to the pre-created extended buffer zone around the same selected random point (EA_backup). The EA_backup had radius of 150 m and 1 km in the urban and rural clusters, respectively. All refusals to participate in the household survey were marked as "refusals" in the tablet questionnaire. Navigation within the EA (and EA_backup) was possible using the GeoODK or Google Maps applications on the interviewers' tablets - this implies that the geographic coordinates of the randomly selected points and the corresponding EA will be provided to the interviewers (Figure 4).

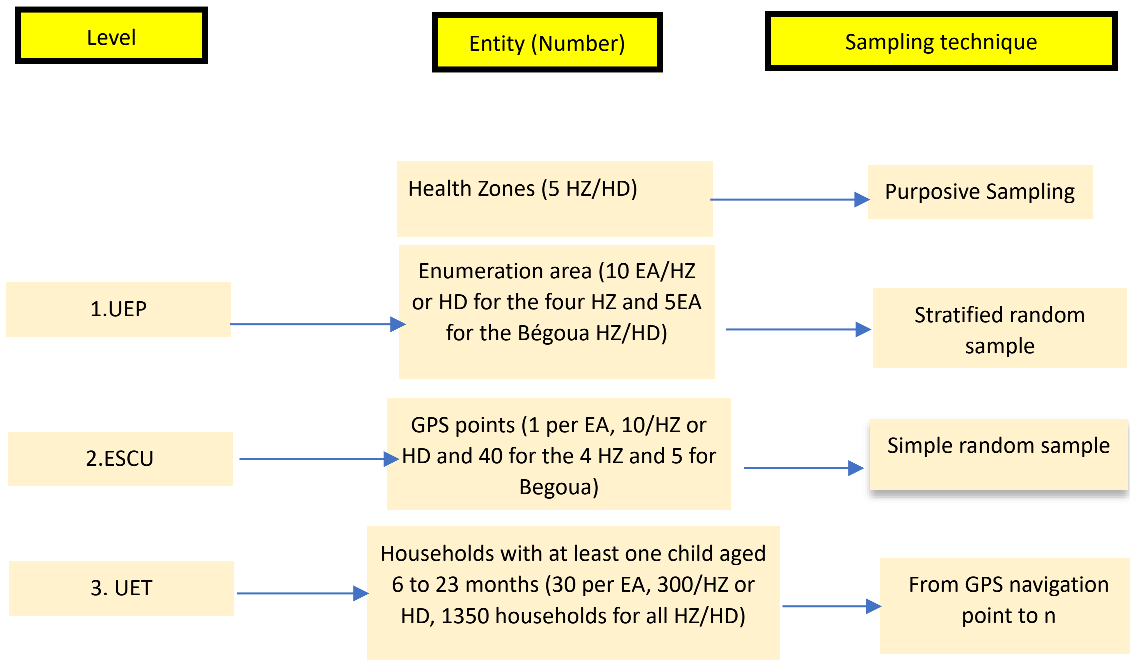

Figure 4. Sampling procedure at different levels for the grid-based GIS method

Lot Quality Assurance Sampling (LQAS)

Lot quality assurance sampling is a random sampling method originally developed by the manufacturing industry and later applied to public health. Typically, a small, simple random sample is taken from a population (or "lot"), and the results are used to classify the lot as "acceptable" or "unacceptable" against a given threshold. As batches are treated as strata, prevalence estimates and standard error can then be calculated for all batches (20, 21).

For this innovation survey, the selected health zones in the DRC or health districts in the CAR were divided into supervision zones . In practice, in both countries, health districts are made up of health areas. These health areas were grouped into 5 strata for this survey. In each stratum, one health area was selected at random. Health areas correspond to urban neighborhoods and rural sectors. Neighborhoods are made up of avenues, and sectors of villages. In each health area, a single avenue/neighborhood or village was selected at simple random, using the list of all avenues or villages provided by local chiefs. In each avenue/neighborhood or village, 19 households with a child aged 6 to 23 months were systematically selected after a pilot survey. If the target of 19 households was not reached in the avenue/quartier or village selected, the collection team moved on to the next avenue/quartier or village until the target of 19 households was reached. If the village was large enough to make it difficult to enumerate all households, it was divided into segments of roughly equal size, and a single segment as drawn at simple random. This segment was then enumerated, and 19 households drawn (Figure 5).

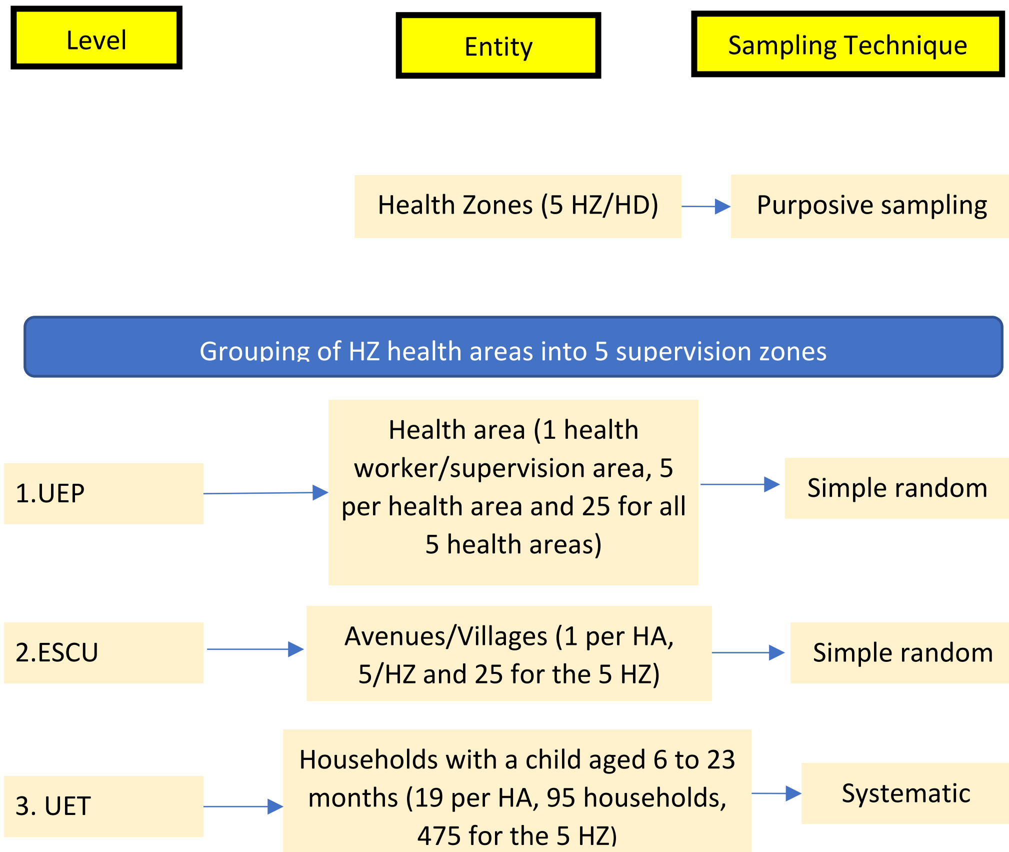

Figure 5. Sampling procedure at different levels for the LQAS method

4.4. *Key Variables*

Comparison of Vaccine Coverage Assessment Methods

For the comparison of vaccine coverage assessment methods, the approach consisted of:

1. Define and measure the results of each method:
   - Number of households listed in a cluster;
   - Number of eligible households identified per cluster;

- Number of eligible households sampled per cluster;
- Number of fully vaccinated children per cluster;
- Number of fully vaccinated children per HD/HZ;
- Proportion of fully vaccinated children per HD/HZ.

2. Define and measure the costs and time associated with each method

   - Average cost of assessing vaccine coverage by method: this is the average cost of assessing vaccine coverage, from training to data collection, via sampling by survey method. It includes the cost of training and implementation, and is expressed in US dollars. The distribution in the form of ranges of costs will also be assessed by method and location.

   - Training cost per method: Includes all costs allocated to training preparation and the training itself, including pre-testing of questionnaires.

   - Cost of implementation by cluster method: Includes all costs allocated to transporting interviewers to the cluster during sampling and data collection, their per diem, fees, interviewer communication costs and survey coordination.

   - Vaccine coverage assessment time by method: This is the average time needed to cover the sampling and data collection process; This time includes fieldwork time and office work time: (1) fieldwork time includes travel time to the cluster from the data collection team's residence, time needed to map households in cluster centers, time to locate the first household, time to find, register and interview households; (2) office work time includes time to define and select clusters and segments, time to produce satellite image prints with household counts.

3. Define a calculation procedure for costs and the times per method

4. Conduct a sensitivity analysis.

A sensitivity analysis consists of varying the average cost of implementation, the average time and the number of fully vaccinated children expected per method per HZ/HD.

The same analysis was carried out to evaluate the variation in the precision of the estimates and the number of clusters to identify the optimal number of clusters per health district.

Details of cost and time measurement are described in a separate document appended to this report.

To measure the relative feasibility of each sampling method, the field teams recorded the arrival and departure times at each PSU. This information was validated against automatic time stamps recorded by cell phones at the beginning and end of each survey recording. At the end of the survey, the teams calculated the number of days required to complete the fieldwork, the average time (in minutes) to complete sampling in a PSU, and the cost of the survey. In addition, at the end of the fieldwork, each team member was asked to complete a qualitative questionnaire to assess their feelings about the complexity, challenges and overall impression of the sampling methodology to which they were assigned. These elements were completed by a series of focus groups organized with the interviewers of the same method.

Household Survey Component

The innovation survey measured the same variables as the MICS vaccination survey. Specifically, information on the following variables was collected:

- Socio-demographic characteristics of household and head of household: location of household, sex and age of head of household, religion of head of household, ethnicity of head of household, occupation of head of household, number of people in household, number of children under 5, number of children 6-11 months, number of children 12-23 months, ownership of assets (electricity, radio, TV, landline telephone, refrigerator, bed, generator, etc.),

- Socio-demographic characteristics of mother/guardian: age, marital status, education, religion, profession, ethnicity.

- Socio-demographic characteristics of the child: age, sex, brachial perimeter;

- Vaccination-related variables: possession of vaccination card, child's vaccination status for each antigen; date of vaccination for each antigen received (day, month, year), participation in a vaccination campaign, vaccines received during vaccination campaigns, reason for non-vaccination, attitude towards child vaccination.

- Demographics: Population distribution by age.

4.5. *Data Collection Technique*

Three main techniques were used to collect data for the study of innovation in immunization coverage surveys: interviewing, observation and document review.

Interviews were conducted with heads of households, mothers/caretakers of children aged 6 to 23 months.

The observation focused on the immunization record book to record the dates on which vaccines were received. In this study, interviewers captured images of children's vaccination cards and send them to the server. If there was an internet connection problem, as in some low-coverage areas, the captures were stored on the tablet and brought back to the coordination team at the end of the data collection for data upload. The coordination team selected two people from the team to transcribe the data from these vaccination card photos for comparison with the interview data.

The document review focused on vaccination registers from health facility. Data from the vaccination registers is to be analyzed at a future date, and was not included in this current report. Analysis will include comparative assessments of those children who did not have a vaccination card available thus guardian recall was used for collecting information on vaccines received compared to information in the health facility registers on vaccines given. Outputs will include the level of agreement between recorded health facility data and guardian recall in terms of child vaccination status.

Vaccination coverage in the present study was measured by three methods:

- Observation of the data on the vaccination card or cards kept at home;
- Recall or verbal history of vaccination;
- Health facility registries: this methodology is advantageous as it employs more documented evidence of vaccination.

As recommended in the WHO manual, health center vaccination records were used if in the cluster where several children were reported vaccinated by mothers/caretakers and if:

- The child's caregiver did not produce a vaccination card;
- The vaccination card shows doses without dates or;
- The card records did not match the vaccinations mentioned by the person taking care of the child.

The teams had the opportunity to visit all the health centers that had vaccinated in the clusters to initiate contacts, obtain documents in advance (photocopies of registers) and assess the quality of the registers (their legibility). Before data collection began, the teams took possession of lists of vaccinators (including those in the private sector), health centers and clinics, with their geographical coverage areas. It is preferable to obtain these lists from the doctor in charge of the health zone or the doctor in charge of the EPI antenna in the DRC, and from the district doctor in charge of the CAR. The teams worked with local guides to help identify and locate vaccination sites frequented by the cluster's population. If the children were vaccinated by private facilities, the investigators also visited these centers to obtain information missing from the vaccination cards.

To facilitate data collection, registers were sometimes borrowed for a few hours and then photocopied or photographed. Where photocopies were obtained in advance, data collection began the day after the questionnaires were filled in.

In cases where a photocopier was not available, data collection teams visited health facilities after the end of data collection in a cluster to complete data on children's immunization status. In cases where the data in a register was difficult to decipher, the teams worked with the original author (healthcare workers that had first recorded the vaccination record).

To facilitate the search for vaccination data in the registers of health facilities, the investigators followed the steps below to find the children in the register:

- Match month and year of birth with corresponding register pages;
- If the entries have a serial number of the same type as the cards, search the register for the card number;
- Match the name of the village or administrative unit on the questionnaire with that of the register;
- Match the child's and parents' names on the card with those on the register. Children often have two names (a familial and official one), making identification more difficult.

Once the child was found in the HA vaccination register, the actual date for each vaccination session was recorded. This data included Vaccine Coverage Quality Indicators (VCQI) derived from the WHO Vaccine Coverage Cluster Survey manual.

4.6. *Data Collection*

Obtaining Ethics Committee Approvals

Prior to data collection, the research protocol was reviewed by the Steering Committees of the Innovation in Rapid Vaccine Coverage Surveys study and submitted to the Ethics Committee for approval.

Recruiting, Training and Organizing Field Teams

The innovation survey coordination teams recruited 28 supervisors, including 12 for the DRC and 16 others for the CAR including those who had already participated in similar studies. These supervisors benefited from three days of training in Bangui and Kinshasa on the objectives and methodology of the innovation survey, the coaching and supervision of investigators, and data quality control. In each HZ/HD, there was a team of 6 people for the WHO method; while for the LQAS method, there was a team of 2 people per health district. Finally, for the KSPH and GIS methods, there were 2 teams of 4 investigators per method per health district. For all methods, 3 additional people per method per HZ/HD were added to the teams during training. A total of 164 field agents including 28 supervisors were trained for all five health districts. At the end of the training in the DRC, 12 trained supervisors and 48 investigators were hired while in the CAR the final team included 16 supervisors and 64 investigators.

Supervisors were responsible for implementing the survey in assigned HZ/HDs. They were responsible for preparing, organizing and directing the fieldwork. As such, they had to ensure that data collection followed the research protocol, and that high quality data was collected. In order to ensure the quality of the work, supervisors and interviewers were recruited from staff who had past experience working with KSPH in DRC, and with ICASEES in Bangui in CAR. All team members had some prior knowledge of vaccination. Interviewers and supervisors were trained at the same time. Notably, no interviewer or supervisor was trained in more than one method – this was to ensure that their approach to sampling (speed, selection strategy, etc.) did not change with time, or between methods. All coverage assessment methods were implemented by a team solely trained for that method. The training included both theoretical and practical aspects. The most important aspects of the training were: (1) the objectives of the survey, the content of the questionnaire and (2) the use of the electronic tablet for data collection. The first day of training was devoted to interview techniques, procedures for obtaining informed consent, and questionnaire content. The following days were devoted to learning/reviewing the use of the tablet for data encoding, sampling techniques, and extracting data from immunization cards and health facility registers. A pre-test was organized at the end of the training in a health area not selected for the study in both countries.

Programming the Tablet with Data Collection Instruments

For all methods, data were collected on tablet computers using the Survey CTO application. The survey used included three sections – household data, information on the mother or caregiver respondent, and information for each eligible child per household.

Programming of the tablet data collection tool was carried out by the data manager selected for this purpose. The standard MICS questionnaire for children under the age of five, in its contextualized immunization component for the DRC and CAR, was adapted to include additional questions on reasons for non-vaccination and knowledge of the importance of immunization.

In addition, questions on the socio-demographic characteristics of the head of household and the mother/caretaker of the 6–23-month-old child were taken from two other MICS questionnaires, namely the "Household" questionnaire (household characteristics) and the "Individual Woman aged 15 - 49" questionnaire (woman characteristics).

Obtaining Authorizations

The KSPH and the Public Health Department of the University of Bangui took the necessary steps to obtain authorizations respectively from the Ministry of Public Health, Hygiene and Prevention for the DRC and the Ministry of Public Health and Population for the CAR. In the field, the data collection teams contacted local health authorities, namely the Head of the Provincial Health Division and the Chief Doctors of the health zones (MCZ) for the DRC, and the Regional Medical Director and the Chief Medical Officer of the health district for the CAR. These visits were used to brief the authorities on the objectives and other important aspects of the study, and to collect data on the size and age composition of the population in the zones/districts and health areas. At the health area level, the data collection teams contacted the heads of district offices or village chiefs to inform them of the start of data collection in their administrative district.

Data Collection using Android Tablets

On a daily basis, the contact details of the selected households (cluster, avenue/village and number) were made available by the supervisors. For the WHO method, 3 teams of 2 interviewers for each HZ/HD which visited 41 clusters of 60 enumerated households each over 12 days to interview 410 households (10 per cluster). For the KSPH method, there were 2 teams of 4 for each HZ/HD (except Begoua) which visited 10/5 clusters and enumerated the area and then visited 30 selected households over 10 days. For the GIS method, the process was similar and data collection was done over 10 days. For the LQAS method, 1 team of 2 interviewers for each HZ/HD plotted each selected axe, and then completed 5 axe clusters with 19 households each for 95 total households per HZ/HD and data collection was done over 10 days. For all methods, teams sent to rural HZ/HD were given two additional days to account for travel to the location.

Once arriving at the site, investigators explained the purpose and procedures to participants and obtained their informed consent before conducting the interview. It is important to note that for reasons of confidentiality, all information collected was coded. All data collected for the survey were encoded on an android tablet using the "Survey CTO" application.

Quality Control of Field Data Collection

The supervisor and the interviewer carried out this process throughout the data collection phase, taking care to observe the following procedure. At the start of each day's work the supervisor identified all the households to be interviewed, insisting that that no household be replaced unilaterally and without authorization. At the end of the working day, the supervisor checked with each interviewer all the data encoded during the day and, if necessary, corrected any errors, either directly or after a second visit to the household. Only after all these checks had been carried out did the supervisor submit the completed form to the server. All data, including GPS coordinates, were transmitted from the interviewer's tablet to a secure virtual server after collection. Access to the server is password-protected. Only the team of investigators and certain members of the Steering Committee had access to the server.

4.7. *Data Processing and Analysis*

Data Submission and Cleaning

Three databases were generated for this survey: (1) the household, (2) the mother/caregiver data and KAP for vaccination, and (3) child 6-23 months vaccination status. Each country had three files from the primary survey that were merged to form one large dataset. Additionally, there was a database generated from data collected from health facility registers and at the central level, vaccination cards were entered by a central team for comparison to entry in the field. This report focuses on findings from survey implementation and the household questionnaire made up of three components.

These databases were then transferred to Stata 15 or other data analysis software for cleaning, processing and analysis. If the values in the databases changed during cleaning, these changes were recorded in a cleaning file. The do-file included either comments or parameters to help understand the reasons for the value change. The most frequently encountered errors included duplication of data and inconsistent data. There were limited issues caused by interviewer skip pattern issues, yet there had been few skip pattern errors identified during data cleaning. The most common skip pattern was that after an interviewer entered the date of birth for the child, they were also asked to enter the value by months – if the value was not between 6-23 months, the child was excluded from data collection vaccination cards, even though it may have just been an error. The duplicates report command was used to search for possible duplicates in the database. Additionally, to identify duplicates, the datasets were searched by individuals on the study team – as it was identified that teams visited the same clusters – but named them different clusters, causing duplicates of children within the same method. There were 63 entries removed due to duplicates. Duplicate observations that arose from the same child being sampled by two different methods were not excluded but noted.

The data manager was responsible for monitoring the sending of data to the server and the downloading of databases. The data analysis co-investigators were responsible for cleaning, processing and analyzing the data.

After cleaning, the first three databases were merged using the identifier: enfant_key. Each household, mother/guardian and child were given a unique ID. There could be duplicates for household and mother IDs, but none for the child ID. The structure of the databases was tested with the pre-test data, so that the data processing and analysis programs could be developed from the outset. A complete list of survey variables, known as the Data Dictionary or Code Book, was created with the database. For each variable, the type (alphabetic or numeric), label and values were defined. At the end of data collection, the codebook was updated with a summary of each database variable. As the data were analyzed using instructions from the WHO's Vaccine Coverage Quality Indicators (VCQI), the variable names and coding conventions listed in the VCQI Forms and Variable List (FVL) document were used in the codebook (4).

Using data collected and qGIS, each cluster for every method was given a unique ID. This was linked to health zone, method and weighting (Table 3).

Table 3. Breakdown of clusters by method and HZ/HD

Cluster	HZ_Method	Cluster	HZ_Method
93 to 133	Boko WHO	41 to 50	Boko GIS
51 to 91	Ndjili WHO	31 to 40	Ndjili GIS
323 to 363	Bangui II WHO	364 to 373	Bangui II GIS
241 to 281	Begoua WHO	374 to 378	Begoua GIS
282 to 322	Bossembele WHO	384 to 388	Bossembele GIS
11 to 21	Boko KSPH	26 to 30	Boko LQAS
1 to 10	Ndjili KSPH	21 to 25	Ndjili LQAS
216 to 225	Bangui II KSPH	201 to 205	Bangui II LQAS
226 to 230	Begoua KSPH	206 to 210	Begoua LQAS
231 to 240	Bossembele KSPH	211 to 215	Bossembele LQAS

Dataset Weighting

To minimize sampling errors, data from each sampling method were weighted using the inverse probability of segment and household selection, respectively. These analyses were performed using the Stata 15 "survey" command or any other data analysis software with similar functionality such as SAS, R. The weighting was used to ensure the estimates were proportionate to expected sample size in each HZ/HD and method combination.

Table 4. Description of weighting process for each method

Method	PSU	SSU	TSU	QSU	ProportionT	Weight
WHO	# AD selected/ total # AD	# eligible HH/# Total HH	# HH selected/# eligible HH	--	PSU x SSU x TSU	1/ProportionT
KSPH	# clusters / total # HA	# eligible HH/# Total HH	# HH selected/# eligible HH	--	PSU x SSU x TSU	1/ProportionT
GIS	# clusters / total # AD	# HH selected/ total # HH	--	--	PSU x SSU	1/ProportionT
LQAS	1/5 (supervision ax)	1/# HA in ax	# eligible HH/# Total HH	# HH selected/# eligible HH	PSU x SSU x TSU x QSU	1/ProportionT

PSU: Primary Sampling unit
SSU: Secondary Sampling unit
TSU: Tertiary Sampling unit
QSU: Quaternary Sampling Unit
AD: Enumeration Area
HA: health area
HH: Household

The following indicator frequency tables have been produced. Certain proportions have been accompanied by 95% Wilson confidence intervals (IC95%):

- Possession of vaccination card;
- Vaccination coverage according to vaccination card;
- Coverage according to mother recall and according to both sources at the same time;
- Proportion of children, overall and by age group, having received BCG vaccine at birth;

- Proportion of children, overall and by age group, having received all doses of OPV vaccine;
- Proportion of children, overall and by age group, having received all 3 doses of Pentavalent vaccine (Penta 3);
- Proportion of children, overall and by age group, having received IPV vaccine;
- Proportion of children, overall and by age group 10 months and older, having received VAR measles vaccine;
- Proportion of children, aged 10 months and over, who received the yellow fever (VAA) vaccine;
- Proportion of children, aged 10 months and over, who received the MenAfrivac (meningitis) vaccine;
- Proportion of children, overall and by age group, who received all three doses of the PCV13 pneumococcal vaccine;
- Proportion of children, aged 10 months and over, who received all vaccines (fully vaccinated children);
- Proportion of children, overall and by age group, who received no vaccine at all;
- Dropout rate between 1st and 3rd dose of Pentavalent;
- Internal validity and concordance between mother/caregiver reporting and health facility registry data.

Proportions were produced using the linearization method; 95% CIs were calculated using Wilson's method to quantify the uncertainty of vaccine coverage estimates. Tables will be presented by HZ/HD.

Since the WHO method is considered the gold standard, to say that the estimates of the KSPH, GIS-KSPH and LQAS methods are close to those of the WHO, the point values of these methods must be included in the confidence interval of the WHO proportion of fully vaccinated children. And that the confidence intervals of these three techniques are around that of WHO±10.

In order to complete the cost analysis, a protocol was developed to capture the costs end to end for implementation. This includes coordination costs, operational costs, and dissemination costs. Implementation costs were calculated by adding training, sampling and data collection costs per method. Comparison was then made between methods, including a sensitivity analysis to determine the type of variation within the selected clusters.

The average time was calculated by adding up the sampling and data collection times for each method. A comparison was then made between methods.

4.8. *Focus Groups and Other Aspects Post-Survey Completion*

Following data collection, focus groups were held with members from each method. This was in the form of informal conversations, semi-structured interviews and group discussions. Additionally, there was a document review and WhatsApp group review with comments that were received while teams were deploying and in the field. This qualitative data was collected between April 2023 and July 2023.

Data was collected on the experiences of various levels and included both things they appreciated about the survey methodology as well as challenges encountered both during cluster selection and implementation in the cluster. Participants were selected on a purposive basis. In each country, a focus group of 6 to 12 people was organized for each method being compared. Focus groups were recorded and transcribed. The analysis followed an inductive thematic approach to content.

When looking at notes taken by the coordination team during preparation, training, implementation and post survey along WhatsApp group messages, additional themes comparing methods were noted. As no interviewer or supervisor had experience with another method, this qualitative data could not provide any comparison method-wise, whereas the coordination worked with all methods. The data was coded according to variables of interest, which consisted of the main themes of the discussion guide for each method.

4.9. *Defining Concepts*

(i) *Fully vaccinated child*: a child is considered fully vaccinated if he or she has received one dose of BCG (protection against tuberculosis), three doses of polio vaccine, three doses of Pentavalent (against diphtheria, tetanus and pertussis, hepatitis B and *Haemophilus influenzae* type b) and one dose of measles vaccine. In recent years, several vaccines have been added to the EPI schedule, including a dose of polio vaccine at birth, a dose of yellow fever vaccine, IPV and 3 doses of pneumococcal vaccine.

(ii) *Vaccination data were obtained from two sources*: the vaccination record or the mother/caregiver's declaration (memory).

(iii) Vaccination coverage indicators have been calculated separately, i.e. if we take the proportion of fully vaccinated children as an illustration, it has been calculated as the proportion of children aged 12 to 23 months who have received all the recommended vaccines on the basis of the vaccination card and on the basis of the maternal booster. They will also be calculated by adding the two sources.

(iv) *Household*: a group of people who live and eat together, and who recognize the authority of a single person called the "head of household".

(v) *Mother or caregiver*: The main respondent in this innovation survey was the mother or carer, for the simple reason that they are the people most likely to know information about the child's health.

(vi) *Health zone/Health district*: In this project, the Health District in CAR corresponds to what is called a Health Zone in DRC.

(vii) *Health area*: In CAR, the health area is a delimited geographical entity, made up of a group of villages in rural areas and/or neighborhoods in urban areas, established according to socio-demographic criteria, with a population size of around 10,000 inhabitants. Each health area is covered by a health center. The same definition applies in the DRC, where the health area is made up of around 5,000 to 10,000 inhabitants, depending on the environment, served by a health center.

4.10. *Ethical Considerations*

Before starting the interview, verbal informed consent was obtained from participants. The consent was included in the data collection questionnaire. The research team provided respondents with information on the following: the nature of the study, its objectives, the risks and benefits involved, the freedom to participate or not without any prejudice, confidentiality, the contact details of the person in charge of the study for further contact if necessary.

The study protocol was submitted for approval to the ethics committees of both countries (CAR N°_9_/UB/FACSS/lPB/CES/023; DRC N°: ESP/CE/028/2023) and the UCLA IRB (IRB No. 23000393).

Thus, on each questionnaire configured on the tablet, the informed consent form was included and accounted for all the information mentioned above. Participant confidentiality was protected as follows: 1. During the interviews, the children's first names were only mentioned to facilitate the conversation, but also to search for them in the Health Center if necessary. They did not appear in the reports. Only members of the research team had temporary access to this information. 2. Access to the server was password-protected. Only the research team and certain members of the steering committee have access to the server. There is no risk involved in taking part in the study, other than taking a little time to answer questions.

The research team was tasked with minimizing the time needed to administer the questionnaire. Training prior to the start of the study enabled the research team to master the survey questions and the questionnaire completion process. One of the expected benefits of this study is the improvement of vaccine coverage assessment procedures for low- and middle-income countries. The data from this study can contribute to the toolbox of vaccine coverage estimation methods adapted to the context of low- and middle-income countries. Study participants' questions and concerns were also taken into account and addressed at any time by the local research team or by one of the study investigators whose contact details appeared on all questionnaire documents. There were no direct benefits to study participants. However, the information from this study will be used to inform future decisions and policies regarding vaccine-preventable diseases and the routine immunization system in the DRC and CAR. Investigators and supervisors were able to adhere to the COVID-19 public health barrier measures - they were equipped with kits containing masks, hydroalcoholic gel, first-aid equipment, and were trained in the use of these materials.

4.11. *Pre-test*

The last day of interviewer/supervisor training was devoted to practice, in a test area selected to mimic real-life work contexts. The scenarios below were: plot survey, household selection and data collection using tablet computers. Interviewers carried out individual interviews on real targets in a health area and in a health center that were not included in the survey. The results of the pre-test were used to assess the interviewer's mastery of the survey methodology and to correct any implementation errors.

5. Project Management and Use of Results

5.1. *Project Administration and Monitoring*

The innovation study on rapid vaccine coverage surveys was coordinated by researchers from the Kinshasa University School of Public Health (KSPH), the Bangui University Department of Public Health and the UCLA Fielding School of Public Health Department of Epidemiology. The Fielding School of Public Health at the University of California, Los Angeles was represented by Professor Anne RIMOIN (PI) and Professor Nicole HOFF (Co-PI). The KSPH/DRC was represented by Professor Didine KABA KINKODI as Principal Investigator (PI), Professor Éric MAFUTA MUSALU as Co-Principal Investigator (Co-PI), Professor Dalau NKAMBA MUKADI as Research Director, Dr Jean Bosco KASONGA NGINDU as Research Assistant and Ms Francine SIMBA MIOLE as administrative and financial manager. The CAR research team was led by Professor Alexandre MANIRAKIZA as PI, Professor Jean de Dieu LONGO as Co-PI, Dr Emmanuel FANDEMA, Research Assistant and Ms. Helga

DIMASSI as Administrative Manager. Other team members are Christian NDJEKOU, Jean Louis KOMAYAN-FANGBILETTE, Franck Elvys MATKOSS, Hugues Edgar ZANGA-GOUMET. The study was funded by the Bill & Melinda Gates Foundation (BMGF), and was represented in CAR by Dr Patrice FEILEMA MOHERESSE, the Foundation's country representative.

The PIs are responsible for carrying out the study in accordance with the research protocol and represent the research teams in discussions with stakeholders. Study funds were managed in accordance with KSPH administrative and financial procedures. In addition, the innovation survey was coordinated by steering committees made up of the EPI of both countries, the BMGF international consultant, WHO, UNICEF, KSPH, UCLA, ICASEES and representatives of the public health department of the University of Bangui. These steering committees were responsible for: (i) approving the research protocol, including methodology, data collection tools and timetable; (ii) monitoring the implementation of the survey; (iii) approving the preliminary report on key findings and the final report. As part of the project monitoring, the two technical teams held regular meetings with each other and with the steering committees, during which the progress of the surveys was discussed.

5.2. *Use and Distribution of Results*

The study of innovation in rapid immunization coverage surveys was conducted primarily to achieve the following objectives:

(i) Estimate vaccination coverage using the four coverage assessment methods in two health zones, one urban and one rural in the DRC, and in three health districts, one urban, one semi-urban and one rural in the CAR;

(ii) Compare each of the three alternative methods to the WHO reference method in terms of effectiveness, cost and time, with the possibility of adopting comparable methods as alternative or supplementary methods that can be replicated in low- and middle-income countries.

Secondly, measuring vaccination coverage rates by health zone/health district will make it possible to:

(iii) Monitor the performance of the routine immunization program at the peripheral level, given that routine reports have some quality challenges;

(iv) Measure the effectiveness of interventions implemented in these districts, particularly supplementary immunization activities (SIAs) in recent years, aimed at increasing immunization coverage;

(v) Identify weak points in immunization programs, for example, by documenting the percentage of children who have not received any vaccine (often an indicator of access to health care), estimating the drop-out rate between the first and last vaccination (a high rate arguing for obstacles to child return and follow-up within the health system, and estimating the frequency of missed vaccination opportunities caused by the absence of simultaneous vaccinations);

(vi) Measure the coverage of vaccines recently introduced into the national immunization schedule and comparing it with the coverage of older vaccines (if the coverage of newer vaccines is lower, this could suggest supply problems and/or deficiencies in awareness, education and communication activities linked to the introduction of the new vaccine).

In order to facilitate the adoption of the results of this innovative survey by the main beneficiaries, the EPI and its technical and financial partners, principally the WHO and UNICEF, representatives of all the parties concerned are involved in the design of this study through a collaborative process. They all observed the entire collaborative process, from the initial discussions between Kinshasa and Bangui, to the design of the research protocol, data collection in the field and final dissemination of the results. In addition, the results of the study were presented to stakeholders at a workshop to discuss methods with expected outcomes. In CAR, the results of this study will also help direct the organization of their first-ever national survey of routine immunization coverage.

6. Activity Timeline

Table 5: Chronogram of activities to implement the protocol

N°	Activities	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Tue-23	Apr-23	May-23	Jui-23	Jul-23	Aug-23	Sep-23
1	Joint UCLA & KSPH team visit to Bangui to meet the Minister and stakeholders involved in RI in CAR												
2	Set-up of the Bangui pilot VCS implementation team, comprising MOH, ICASEES and PH Department)												
3	Debriefing of the authorities and preparation of the KSPH mission to Bangui to accompany the implementation team.												
4	Drafting and validation of the protocol for the pilot study on the comparison of VCS methods												
5	Mission of the KSPH team to Bangui to support the research team (drafting the protocol and administrative aspects).												
6	Translation of protocol into English and sharing with partners												
7	Steering committee meeting in Kinshasa												
8	Obtaining authorization from the Ethics Committee												
9	Implementing the questionnaire on tablets												
10	Supervisor/investigator recruitment												
11	Supervisor/investigator training												
12	Pre-testing and adaptation of media												
13	Team deployment												
14	Data collection												
15	Data processing and analysis and sharing of results												
16	Results validation meeting												

7. Budget

The estimated budget was planned before deployment based on historical costs from the national VCS surveys implemented in DRC, as well as previous surveys using the other alternative methods. The total budgeted cost was comparable to the estimated total and is broken down further for the cost analysis portion of this report (Table 6).

Table 6: Overall budget for the comparative pilot study of vaccine coverage methods in 2 DRC health zones and 3 CAR health districts, broken down by method

Section	**DRC**		**CAR**	
Direct cost (CD) budget	**Total budgeted cost USD**	**%**	**Total budgeted cost USD**	**%**
Buy tablets	$0.00	0.0	$6 000.00	5.4
Training preparation workshop	$1 240.00	1.1	$1 240.00	1.1
WHO method	$33 900.00	31.0	$35 340.00	31.7
KSPH method	$22 760.00	20.8	$23 660.00	21.3
GIS method	$22 760.00	20.8	$23 660.00	21.3
LQAS method	$10 110.00	9.3	$10 430.00	9.4
Results workshop	$6 750.00	6.2	$6 750.00	6.1
Total Direct costs (CD)	$97 520.00	89.3	$107 080.00	96.2
Indirect cost (IC)				
Administrative/Banking costs	$9 752.00	8.9	$2 141.60	1.9
Ethics committee review fee (2% of CD)	$1 950.40	1.8	$2 141.60	1.9
Total IC	$11 702.40	10.7	$4 283.20	3.9
Grand total	**$109 222.40**	**100.0**	**$111 363.20**	**100.0**

8. Results

8.1. *Study Implementation - Sample Description*

Site Selection

The comparative survey of vaccine coverage assessment methods was conducted in 5 HZ/HD. In each HZ/HD, all four methods were implemented. Figures 6 and 7 show the geographical distribution of surveyed households, represented by the dots in the figures below, by method in the HZ/HD of N'djili, Kinshasa and Boko, Kwango in the DRC. In these HZs, for all methods, the households surveyed fell within the selected clusters. However, after collection, one cluster (50) in Boko was determined to be outside Boko health zone and was excluded from all analysis. In CAR, three HD were included, Bangui II, Begoua and Bossembele. As mentioned earlier, Begoua only had 5 clusters selected for KSPH and GIS. Additionally, during data analysis, it was determined that 6 clusters in the GIS Bossembele survey were not in the correctly selected cluster – these were excluded from all analysis – and only 4 clusters were retained. Additionally, the Bangui 2 WHO team did not correctly label their clusters – and instead of labeling 1 to 41, they numbered based on their day of collection, thus after collection the coordination team regrouped the clusters to have 41 clusters. Below are maps (figures 6-10) of the cluster distribution in each health zone for all methods. For the KSPH method, the sub-segments selected were: 2, 4, 5, 10, 12, 14. Alternative segments were selected in-field in the event that these segments did not have any inhabitants or did not have enough inhabitants to complete the 30 households. During analysis, the coordination team identified that in over 50% of the sub-clusters, the 5 houses per sub-cluster were not respected, and additionally when mapping clusters – there was often not a defined sub-segmentation for all clusters. Thus, the decision was made not to add the additional weighing probability for sub-clusters, as this was expected to make the 95% CI seem smaller than they may have been in reality due to difficulty implementing this process.

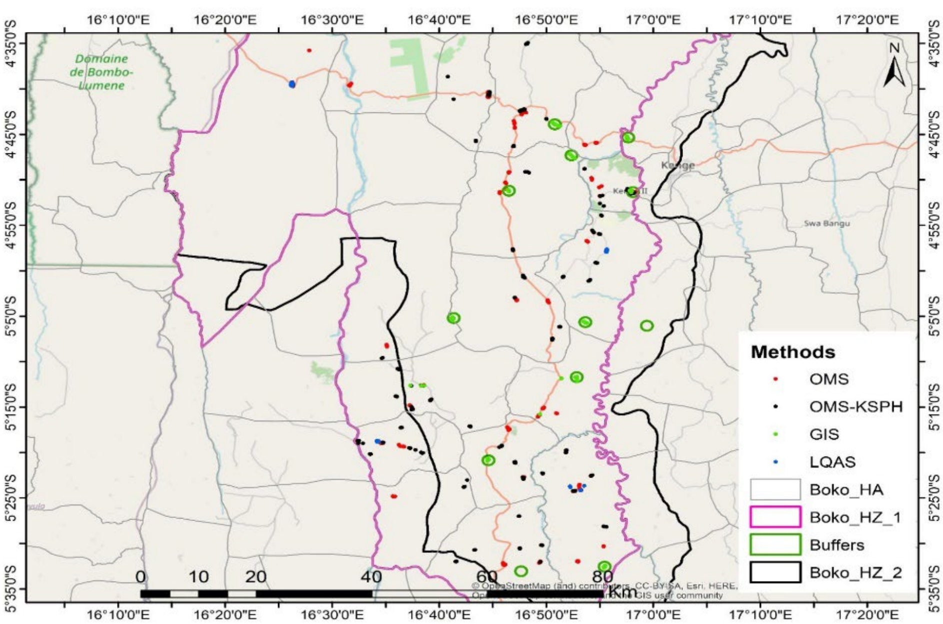

Figure 6: Mapping of the VCS 2023 comparative survey in the Boko Health Zone

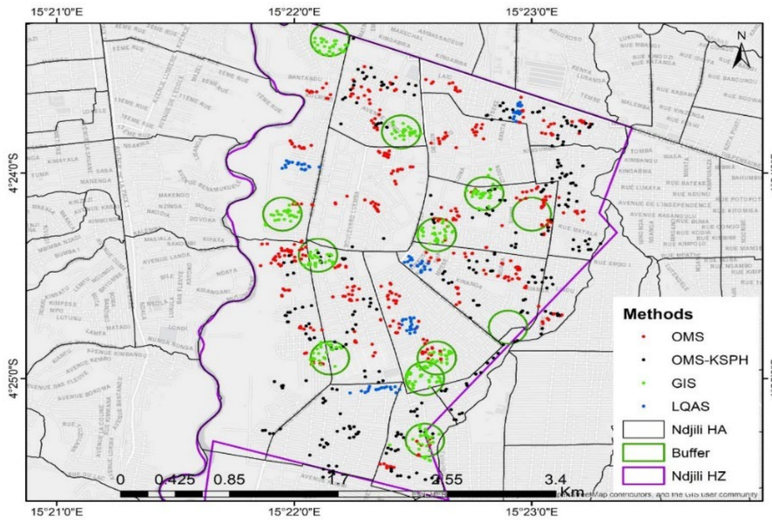

Figure 7: Mapping of the comparative survey of VCS 2023 methods in the N'DJILI Health Zone

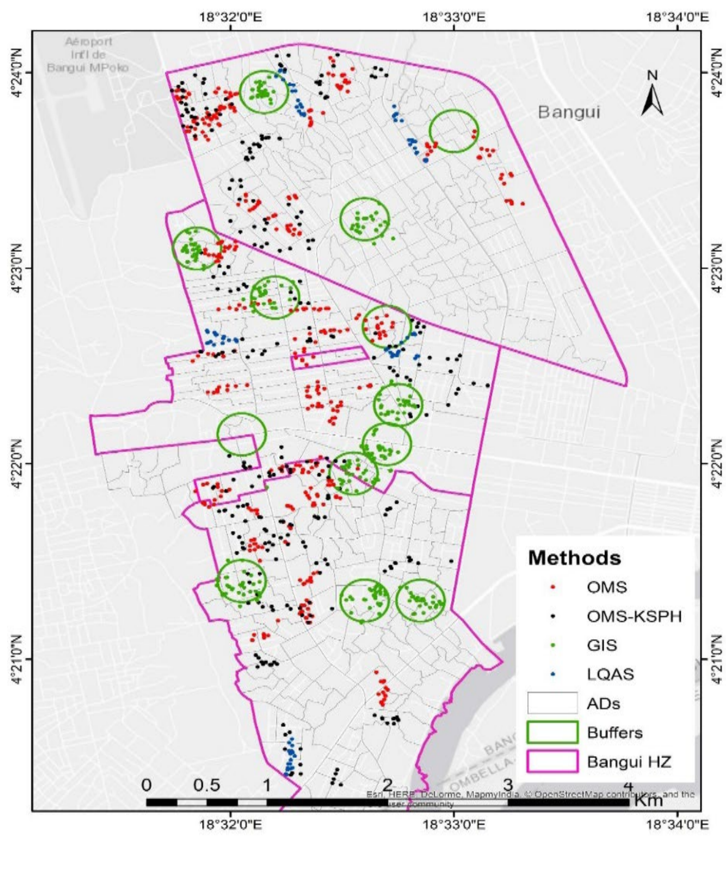

Figure 8: Mapping of the VCS 2023 comparative survey in the BANGUI II Health District

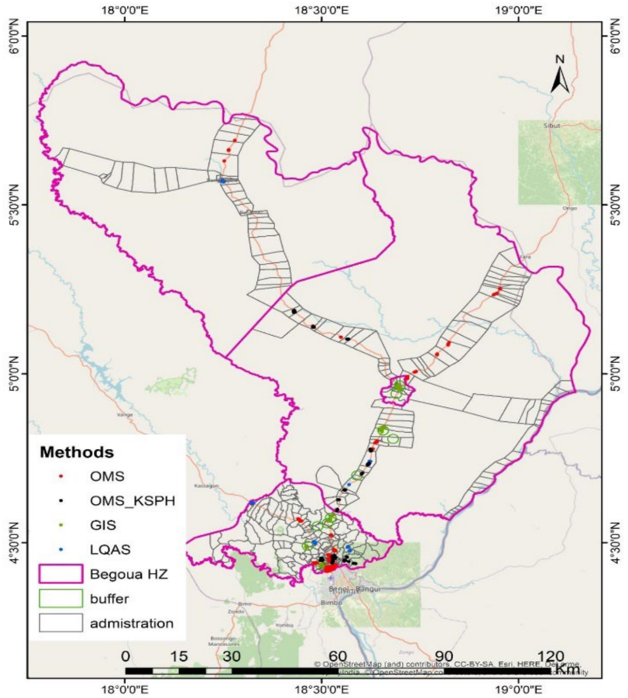

Figure 9: Mapping of the comparative survey of VCS 2023 methods in the BEGOUA Health District

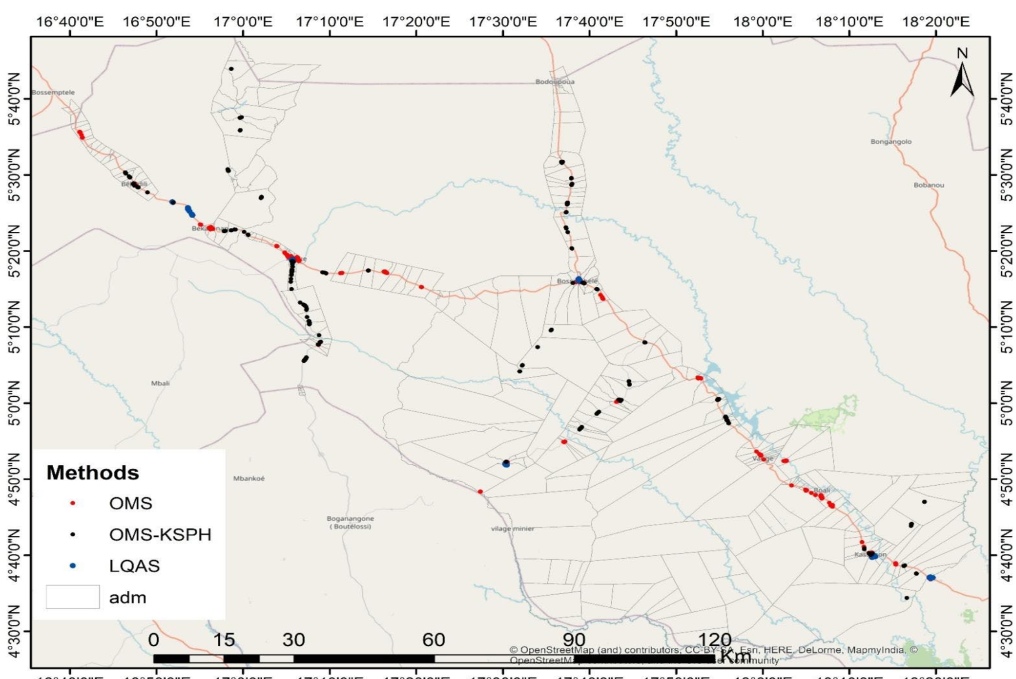

Figure 10: Mapping of the comparative survey of VCS 2023 methods in the BOSSEMBELE Health District

KSPH and GIS Method: Five Cluster Selection

While 10 KSPH and GIS clusters were selected for 4 of the HZ/HD, results of this report will only be shown for 5 selected clusters in each HZ. In Begoua, only 5 clusters were selected. In Bossembele only 4 clusters were correctly selected. In the remaining 4 HZ/HD, the coordination team randomly selected 5 clusters to represent the results of the 5 clusters that would have been selected for the study if implemented to protocol. Data on the full clusters will be available as requested. For data simulations (section 8.5) and cost analysis (section 8.6) all clusters completed were included. To obtain the results for five clusters, we carried out a random selection process. First, we generated combinations of ten numbers taken 5 at a time. Once all possibilities were mapped, a random number generator was used to select which permutation of 5 clusters would be selected for analysis.

Sample Description

In total, 5,209 households consented to participate in the study: 2,993 in CAR and 2,216 in DRC (Table 7). Of these 5209 households, 5,255 mothers/caregivers of children aged 6-23 months were interviewed and data from 5,332 children aged 6-23 months were collected. Out of 5,332 children surveyed, 1,541 children in the two countries did not have vaccination records (682 in the DRC and 859 in the CAR), among whom 406 (151 in the DRC and 255 in the CAR) children had never received a vaccine. Of these children, vaccination coverage of 1,135 was solely based on mother/caregiver recall. In total, 3,791 (1,582 in DRC and 2,209 in CAR) children had physical vaccination records (Figure 11).

Table 7: Number of sample clusters, households, children aged 6-11 months and 12-23 months in these clusters - original and adjusted proportions

		Original						Adjusted					
Health Zone/Health District	Method	Clusters	Households	Mother/Guardian	Children 6-23 months	Children 6-11 months	Children 12-23 months	Clusters	Households	Mother/Guardian	Children 6-23 months	Children 6-11 months	Children 12-23 months
DRC-Boko	WHO	41	408	409	415	166	249	41	408	409	415	166	249
	WHO-KSPH	10	299	306	308	124	184	5	149	150	151	62	89
	GIS	9	306	307	311	121	190	5	152	153	155	61	94
	LQAS	5	87	87	87	35	52	5	87	87	87	35	52
DRC-Ndjili	WHO	41	418	419	424	169	255	41	418	419	424	169	255
	WHO-KSPH	10	299	302	311	126	185	5	149	150	152	62	90
	GIS	10	305	305	309	154	155	5	157	157	158	74	84
	LQAS	5	94	96	99	41	58	5	94	96	99	41	58
CAR-Bangui II	WHO	41	396	403	404	159	245	41	396	403	404	159	245
	WHO-KSPH	10	303	307	316	108	208	5	155	155	159	53	106
	GIS	10	302	304	307	131	176	5	151	152	153	72	81
	LQAS	5	95	97	98	43	55	5	95	97	98	43	55
CAR-Begoua	WHO	41	409	415	423	151	272	41	409	415	423	151	272
	WHO-KSPH	5	134	136	138	47	91	5	134	136	138	47	91
	GIS	5	150	150	154	60	94	5	150	150	154	60	94
	LQAS	5	96	96	98	37	61	5	96	96	98	37	61
CAR-Bossembele	WHO	41	381	385	389	128	261	41	381	385	389	128	261
	WHO-KSPH	10	336	337	341	145	196	5	170	171	172	82	90
	GIS	10	296	296	299	114	185	4	113	113	113	48	65
	LQAS	5	95	98	101	42	59	5	95	98	101	42	59
Total			**5209**	**5255**	**5332**	**2101**	**3231**		**3959**	**3992**	**4043**	**1592**	**2451**

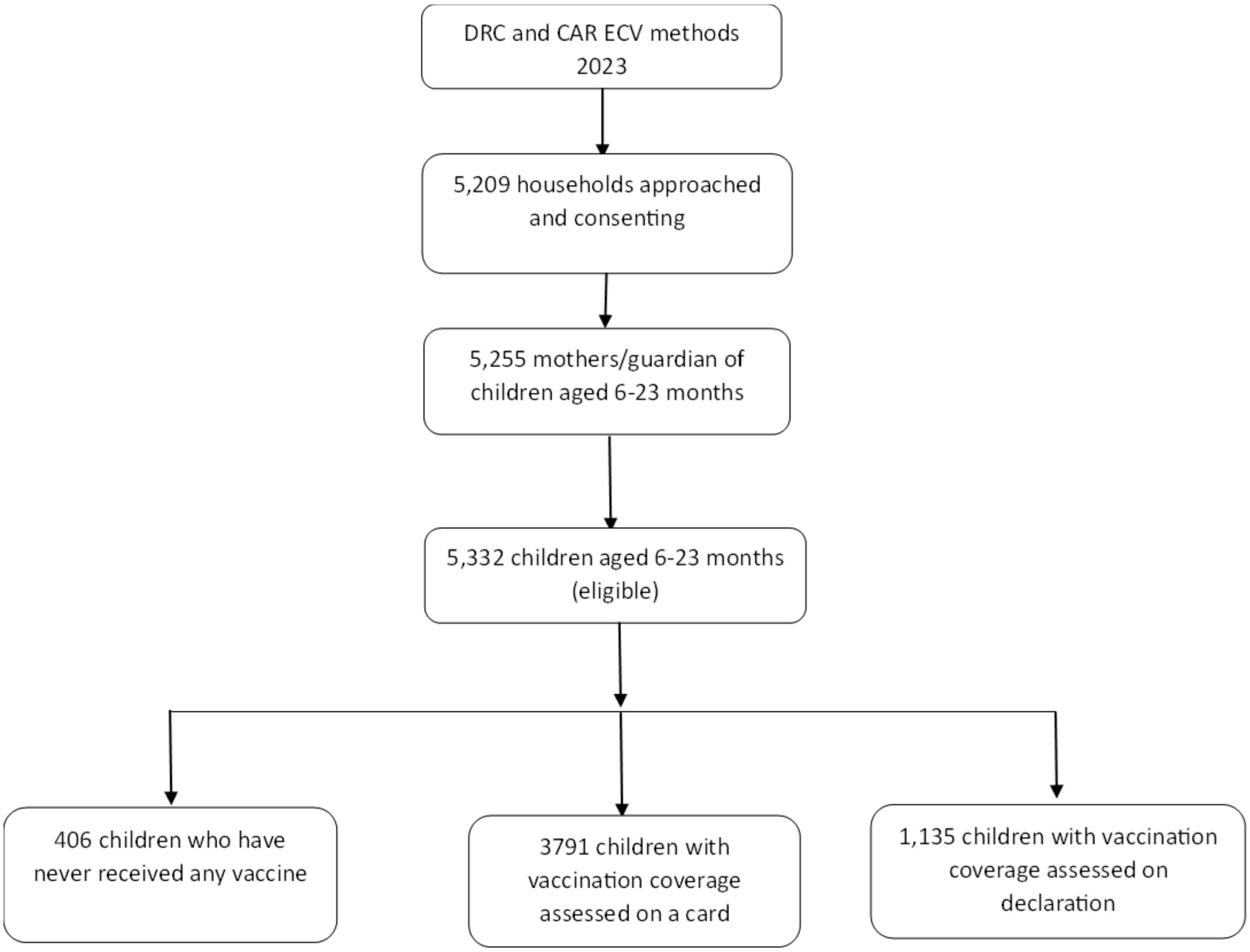

Figure 11: Flow chart of participation in the comparative survey of VCS 2023 methods in DRC and CAR for the WHO method

8.2. *Socio-demographic Characteristics*

While many socio-demographic factors were collected as a part of this survey, the purpose of this study was to compare the primary outcomes of vaccine coverage by accuracy, cost and time. Thus, only selected variables from the socio-demographic variables will be included in this report.

The majority of respondents to this VCS 2023 were mothers of children. Overall, Boko had the lowest number of mother respondents (81.1%) while fathers represented in some methods over 20%. Begoua and N'djili had the highest number of mother respondents (93.9% and 96.3%, respectively). Additionally, there was very limited variation between the methods (Table 8).

Table 8: Distribution of respondent type by District and by method in DRC and CAR during the VCS 2023 comparative survey (VCS-2023)

Health Zone/Health	Method	Households	Mother (%)	Father (%)	Child guardian (%)
DRC-Boko	WHO	408	81.1	14.2	4.8
	WHO-KSPH	149	65.8	28.1	6.1
	GIS	152	85.8	10.9	3.3
	LQAS	87	75.8	15.7	8.6
DRC-Ndjili	WHO	418	96.3	0.8	2.9
	WHO-KSPH	149	96.6	0.8	2.6
	GIS	157	97.1	1.2	1.7
	LQAS	94	95.8	0,0	4.2
CAR-Bangui II	WHO	396	93.7	3,0	3.2
	WHO-KSPH	155	95.3	3.4	1.3
	GIS	151	91.6	3.7	4.7
	LQAS	95	95.4	0,0	4.6
CAR-Begoua	WHO	409	93.9	3.7	2.4
	WHO-KSPH	134	97.4	2.6	0,0
	GIS	150	91.4	4.7	3.9
	LQAS	96	95.4	2.3	2.4
CAR-Bossembele	WHO	381	91.8	7.1	1.1
	WHO-KSPH	170	81.9	15.1	3.1
	GIS	113	87.6	8,0	4.4
	LQAS	95	97.6	1.5	0.9

When looking at religion, the majority of DRC respondents were members of revivalist/independent churches, followed by those who identify as Protestant and Catholic. In CAR, in all health districts and for all methods, most respondents were Protestant and Catholic. In Bangui II (urban health district), the greatest proportion of respondents were Muslim (Table 9).

Table 9: Distribution of mothers/caretakers of children aged 6-23 months according to religion by District and by method in the DRC and CAR during the VCS 2023 comparative survey (VCS-2023)

Health zone/Health district	Method	Mother/guardian	Animist/No religion %	Catholic %	Protestant %	Kimbanguist %	Muslim %	Revival Church/Independant %	Others %
DRC-Boko	WHO	409	2.4	24.4	23.8	5.9	0.7	40.0	2.9
	WHO-KSPH	150	0.0	33.1	23.8	5.8	0.6	27.8	9.0
	GIS	153	0.6	14.7	25.5	4.8	0.0	39.0	15.5
	LQAS	87	0.0	22.4	50.8	4.9	0.0	11.0	10.9
DRC-Ndjili	WHO	419	0.0	9.8	7.1	4.2	0.6	68.4	9.8
	WHO-KSPH	150	0.0	11.4	20.3	4.1	0.8	59.9	3.5
	GIS	157	0.5	12.0	9.8	1.8	0.0	71.2	4.8
	LQAS	96	0.0	7.4	19.8	6.1	1.2	63.3	2.2
CAR-Bangui II	WHO	403	0.0	30.9	37.2	0.5	24.2	4.1	3.1
	WHO-KSPH	155	1.3	36.0	35.2	1.4	21.3	4.2	0.6
	GIS	152	0.0	19.0	36.6	0.5	41.1	2.0	0.8
	LQAS	97	0.0	11.4	51.4	0.0	37.2	0.0	0,0
CAR-Begoua	WHO	415	0.0	23.4	56.9	0.0	0.2	1.8	17.7
	WHO-KSPH	136	0.0	25.9	57.2	0.0	0.6	3.1	13.2
	GIS	150	0.0	17.6	69.5	0.0	0.0	3.8	9.1
	LQAS	96	0.0	15.9	80.4	0.0	1.8	0.0	1.8
CAR-Bossembele	WHO	385	7.7	19.6	49.2	0.0	2.2	16.0	5.3
	WHO-KSPH	171	0.0	18.1	62.4	0.0	4.1	8.0	7.5
	GIS	113	0.0	10.3	74.8	0.0	0.0	10.7	4.3
	LQAS	98	1.4	12.4	82.2	0.0	0.0	0.0	3.9

The majority of respondents in VCS 2023 had completed secondary school. This was the case in the DRC, in all health zones and for all methods. The WHO method in Boko was the exception, where the majority had only completed primary education. Higher education was achieved by respondents in the urban health zone of N'djili, while in the rural health zone of Boko, few respondents had higher education. In CAR's Bangui II health district, the majority of respondents had completed secondary education, followed by primary education for all methods. In Begoua, primary education completion was most common for the KSPH, GIS and LQAS methods, while for the WHO method, secondary school completion was most common (50.1%). In the rural district of Bossembele, most respondents only had primary school education. Higher education was poorly represented in CAR, ranging from 0.0% in Bossembele to 7.3% of respondents in Bangui II (Table 10).

Table 10: Distribution of mothers/caregivers of children aged 6-23 months according to highest level of education achieved by District and by method in DRC and CAR during the VCS 2023 comparative survey (VCS-2023)

Health zone/Health district	Method	Mother/guardian	Never went to school %	Primary %	Secondary %	Superior %	Others %
DRC-Boko	WHO	409	16.7	45.8	36.6	1.0	0.0
	WHO-KSPH	150	31.5	26.3	40.3	1.9	0.0
	GIS	153	18.2	25.3	56.0	0.5	0.0
	LQAS	87	20.0	31.2	45.6	3.2	0.0
DRC-Ndjili	WHO	419	0.2	3.3	76.9	19.6	0.0
	WHO-KSPH	150	1.6	5.5	75.8	16.5	0.6
	GIS	157	0.0	4.3	81.1	14.2	0.5
	LQAS	96	0.0	2.1	79.4	18.5	0.0
CAR-Bangui II	WHO	403	16.2	22.5	54.0	7.3	0.0
	WHO-KSPH	155	13.4	21.8	60.7	4.1	0.0
	GIS	152	10.0	39.1	46.3	4.7	0.0
	LQAS	97	24.5	29.1	44.1	2.4	0.0
CAR-Begoua	WHO	415	7.2	38.2	50.1	4.5	0.0
	WHO-KSPH	136	10.3	38.3	42.4	4.5	4.5
	GIS	150	10.4	56.8	32.2	0.6	0.0
	LQAS	96	23.1	54.0	22.4	0.0	0.5
CAR-Bossembele	WHO	385	26.2	58.4	15.0	0.1	0.3
	WHO-KSPH	171	45.6	47.8	6.6	0.0	0.0
	GIS	113	22.1	68.8	9.1	0.0	0.0
	LQAS	98	31.1	46.8	21.2	0.0	0.9

8.3. *Survey Results – Precision*

Observed Design Effects

While this document focuses on the assumed design effects used to select sample sizes, each method reports “observed” design effects (deff) as described in the methods. Below is the summary of the design effects by health district and method for the “fully-vaccinated" outcome.

Table 11: Observed Design Effects (deff) by Method and Health Zone

HZ/HD	WHO	WHO-KSPH	GIS	LQAS
DRC N’djili	1.368	3.854	2.143	0.421
DRC Boko	1.695	1.567	8.880	2.367
CAR Bangui II	1.086	0.822	0.953	0.822
CAR Bégoua	1.862	1.092	1.475	1.289
CAR Bossembele	2.043	2.091	1.012	2.270

Proportion of Vaccination Card Holders

As a part of the questionnaire, respondents were asked to present a vaccination card or some other document which indicated the vaccines the child received. The interviewer was instructed to take a picture of this document (if present) and enter all information from the card to the survey. Of note, out of the 3791 children who reported having a card, 133 did not present the card to the interviewer. Vaccination card/booklet ownership varied by district and by method. Using the WHO method, it was 63.3% in Boko and 69.4% in N'djili in the DRC. It was 83% in Bangui II, 82.1% in Begoua and 61.2% in Bossembele in CAR (Table 12). If data was not collected from a vaccination card, it was collected through respondent recall. In this case each vaccine was described to the respondent – including time and location of where the vaccine would be given to help remind respondents of vaccines received.

Table 12: Proportion of households with vaccination cards/books

Health zone/Health district	Method	n	Yes (%)	No (%)
DRC-Boko	WHO	408	63.5	36.5
	WHO-KSPH	149	46.3	53.7
	GIS	152	58.5	41.5
	LQAS	87	61.1	38.9
DRC-Ndjili	WHO	418	69.6	30.4
	WHO-KSPH	149	76.8	23.2
	GIS	157	93.6	6.4
	LQAS	94	62.5	37.5
CAR-Bangui II	WHO	396	83.1	16.9
	WHO-KSPH	155	90.0	10.0
	GIS	151	91.8	8.2
	LQAS	95	81.1	18.9
CAR-Begoua	WHO	409	82.9	17.1
	WHO-KSPH	134	96.0	4.0
	GIS	150	60.5	39.5
	LQAS	96	63.2	36.8
CAR-Bossembele	WHO	381	61.3	38.7
	WHO-KSPH	170	45.4	54.6
	GIS	113	33.0	67.0
	LQAS	95	59.4	40.6

Proportion of Fully Vaccinated Children Aged 12-23 Months

While all children 6-23 months were enrolled in this study, the results display 2 groups of children into 12-23 months (primary outcome) and 6-11 months. This is due to the fact that children under 12 months may still not be fully immunized and those under 9 months would not have been vaccinated for yellow fever, measles and in CAR, meningitis. For this report, if a respondent was unsure if or how many doses of a vaccine a child received or if they refused to respond, or there was not adequate information to determine if the child had been vaccinated, the response was coded to "no." If a child vaccination card indicated that a child had received a subsequent (penta2 or 3 for example) vaccine and no penta1, these were recoded to indicate penta1 and penta2 – this was done for all three dose vaccines. We assumed if a vaccine was not listed, we could not confirm if a child had received it. Additionally, complete vaccination was based on a respondent reporting or the vaccination card indicating that a child had received: 1 dose BCG, 3 doses of Pentavalent, 3 doses of Pnuemo13, 3 doses of OPV, 1 dose of IPV, 1 dose of VAR (measles) and 1 dose of VAA (yellow fever). In DRC, children are also given 3 doses of Rotavirus vaccine at the same time as Penta, Pneumo13 and OPV, and in CAR children are given MENAfric (meningitis) at the same time as VAA and VAR. As these differed between the countries, they were not included as a part of the complete vaccination – but are presented individually in this report.

Overall, the Bossembele HD showed low vaccination coverage for all methods, with the proportion of children aged 12-23 months fully vaccinated ranging from 6.2% for the GIS method to 26.6% for the LQAS method. In the DRC, in all methods, the N'djili HZ had high coverage compared with the Boko HZ (Table 13 and Figure 12). This report is data dense, thus tables and figures are presented to help the reader visualize results presented.

In general, for most HZ/HD, the CI for WHO were the smallest – as expected with the most clusters per HZ/HD. However, we additionally saw that many of the CIs for the other methods overlapped with the WHO method. However, it would not be recommended to use the results of the other method at the HZ/HD level, without a number of limitations as to what can be interpreted.

Table 13: Proportion of children aged 12-23 months fully vaccinated in pilot study HZ/HD in DRC and CAR, 2023

Health zone/ Health	WHO			WHO-KSPH			GIS			LQAS		
District	n	%	IC 95%	n	%	IC 95%	n	%	IC 95%	n	%	IC 95%
DRC - Boko	249	32,7	[25,8-40,5]	89	15,0	[7,9-26,7]	94	32,6	[11,7-63,8]	52	35,7	[18,7-57,4]
DRC - Ndjili	255	59,3	[52,4-65,9]	90	64,3	[43,6-80,7]	84	77,7	[62,2-88,1]	58	52,6	[44,3-60,8]
CAR - Bangui	245	44,8	[38,5-51,3]	106	43,8	[35,7-52,2]	81	56,2	[45,5-66,4]	55	52,2	[40,4-63,7]
CAR - Begoua	272	38,6	[31,1-46,7]	91	60,9	[50,4-70,4]	94	15,5	[8,6-26,4]	61	19,6	[10,6-33,4]
CAR - Bossembele	261	14,6	[9,5-21,7]	90	6,7	[2,2-18,9]	65	6,2	[2,3-15,3]	59	26,6	[13,1-46,5]

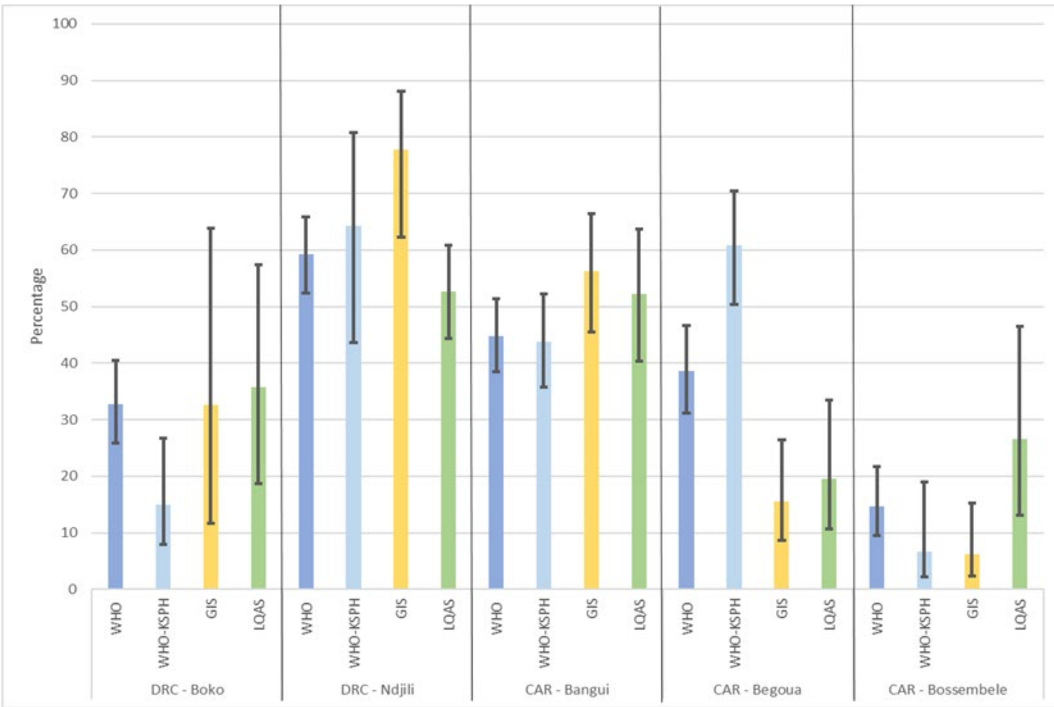

Figure 12: Estimates of complete vaccination by health zone and vaccine coverage assessment method for VCS 2023

Proportion of Children Aged 12 to 23 months who Received Pentavalent 3 and VAR

While data was collected for all routine vaccines, this report focuses on Pentavalent3 (Penta3) and VAR. Data is available in the appendix for every antigen (Appendix 1). Point estimates and confidence intervals for the proportion of children aged 12-23 months vaccinated with dose 3 of Pentavalent in HZ/HD by method (Figure 13). These results are from combined vaccination card and respondent recall.

Overall, rural health districts in CAR and DRC showed low Penta3 coverage for all methods. Bossembele HD had the greatest variation in estimates of Penta3 coverage by method and ranged from 15.3% (CI95%: [9,4-23,9]) for the WHO-KSPH method Bossembele to 52.4% (95CI [35,6-68,6]) for the LQAS method. Overall, the CIs indicate a general overlap between methods for most of the HZ/HD. The LQAS and GIS method had the highest level of variance compared to the WHO and KSPH method.

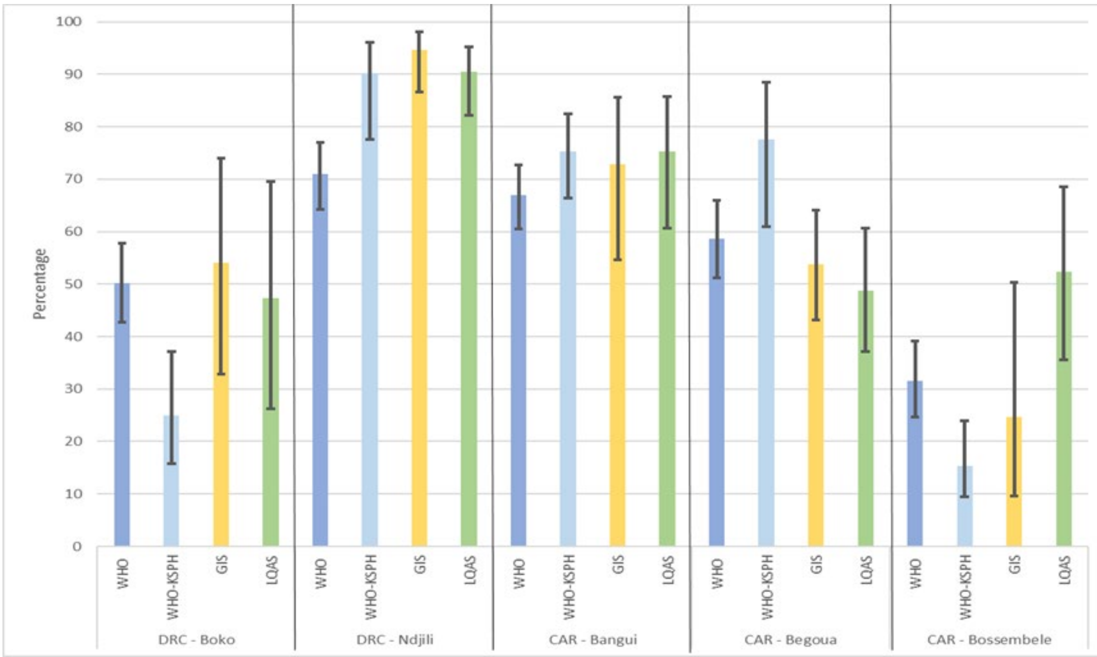

Figure 13: Estimates of Penta3 coverage by health zones and vaccine coverage assessment method

Overall, rural health districts in CAR and DRC showed lower VAR coverage for all methods (Figure 14). For example, in Boko, vaccination coverage of children aged 12-23 months vaccinated with VAR ranged from 44.1% for the LQAS method to 49.5% for the WHO method.

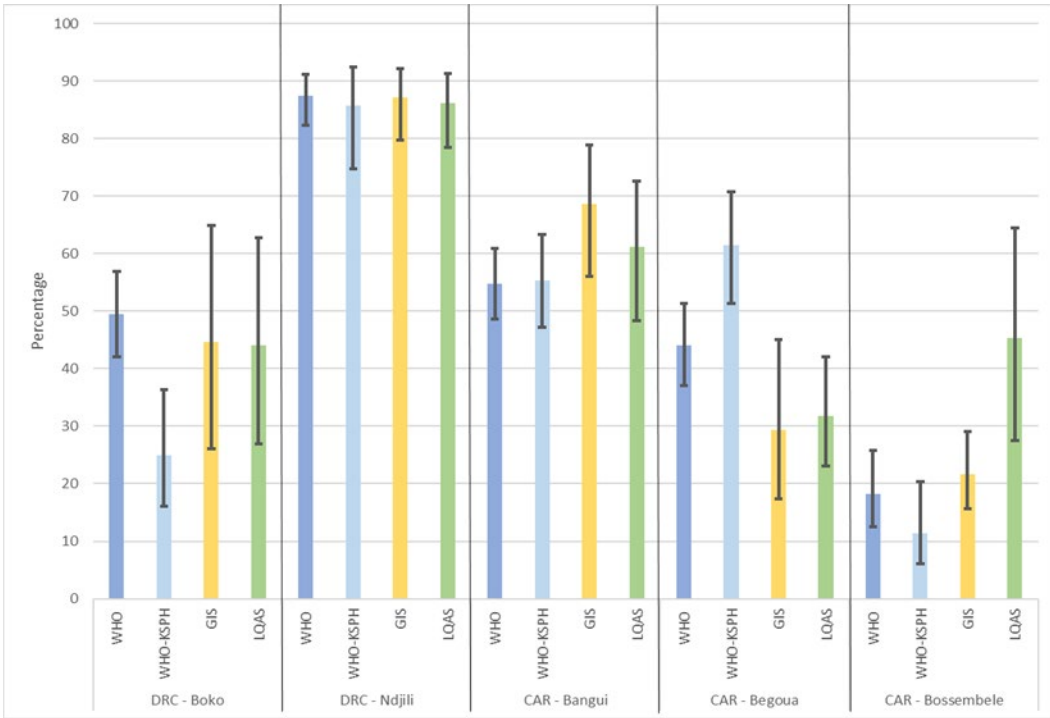

Figure 14: Estimates of VAR coverage by health zone and vaccine coverage assessment method

Drop-out Rate per Antigen for Multi-dose Vaccines

Vaccination dropout was estimated by the proportion of children who had been vaccinated with Penta1 but had not received Penta3 (Figure 15).

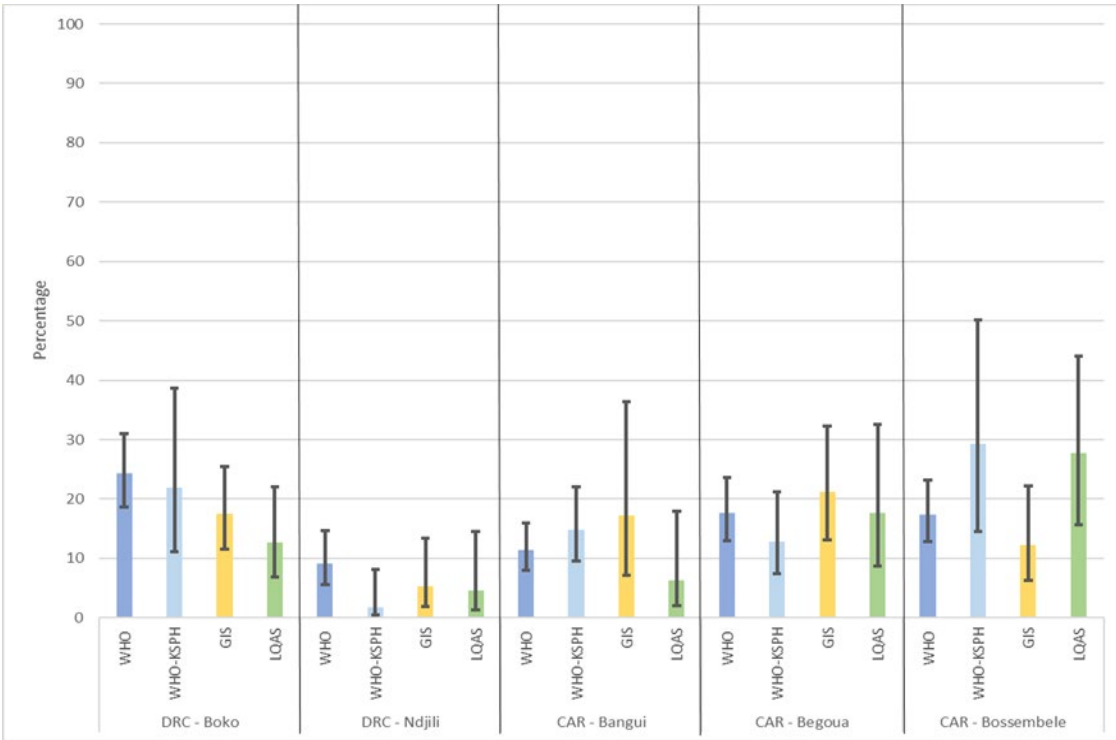

Figure 15: Estimates of vaccination dropout by health zone and vaccination coverage assessment method

Proportion of Children Aged 12 to 23 Months Considered "Zero Dose"

Gavi has indicated the definition for zero dose children as being calculated as 100% - % penta1. This is the definition used for this report. Overall, the rural HZ/HDs in CAR and DRC had the highest proportions of 12–23-month-old children who were zero-dose for all methods (Figure 16). It should be noted, when the percentage was closer to zero – all methods had very low variation in the CI. However, with higher point estimates, such as in Boko and Bossembele, increased variance was observed.

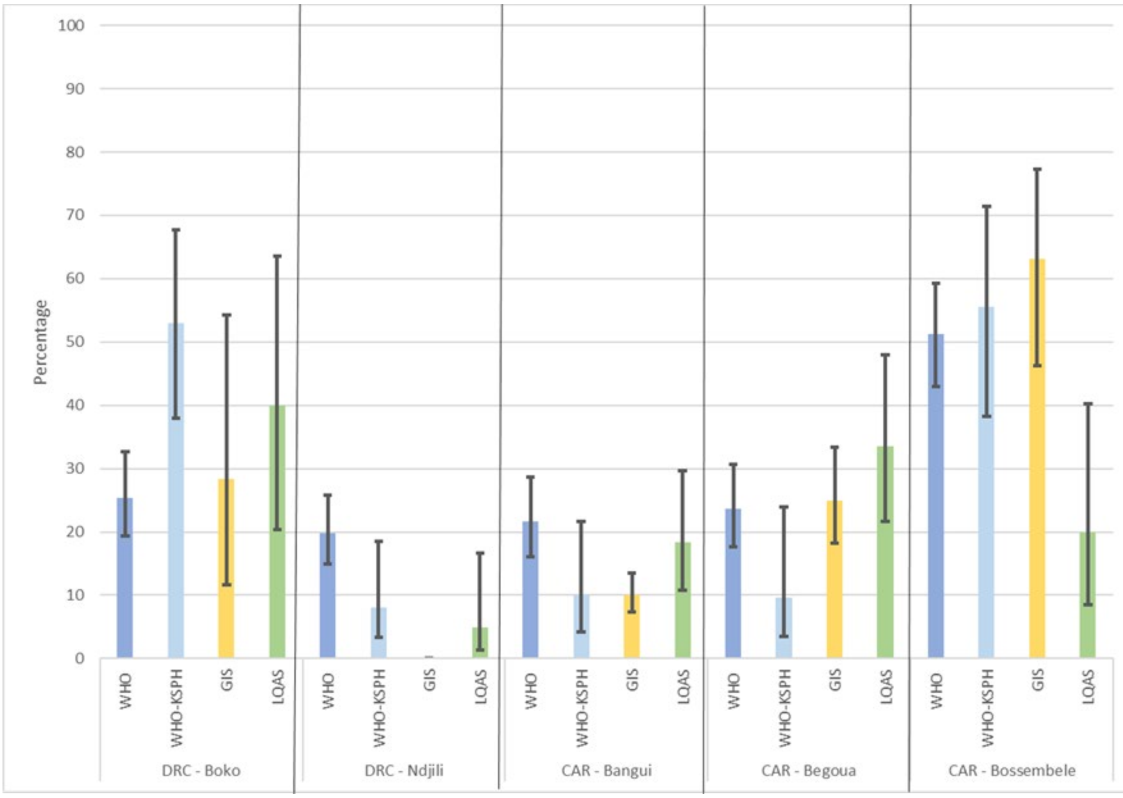

Figure 16: Estimates of "zero-dose" children aged 12-23 months by health zone and vaccine coverage assessment method

Proportion of Children Aged 6 to 11 Months Vaccinated for Selected Vaccines

For children under 12 months, it is possible many may not be completely vaccinated. Thus, for this age group, trends in BCG vaccination and Penta1 vaccination were explored. These figures can provide information on real time vaccination coverage estimates and could lead to direct recommendations for helping to ensure children in this age range are reached for complete vaccination. Overall, rural HZ/HDs in CAR and DRC had the lowest proportions of 6–11-month-old children vaccinated with BCG for all methods (Figure 17). For example, in Boko, the proportion of children aged 6-11 months having received BCG ranged from 58.3% for the GIS method to 84.3% for the WHO method.

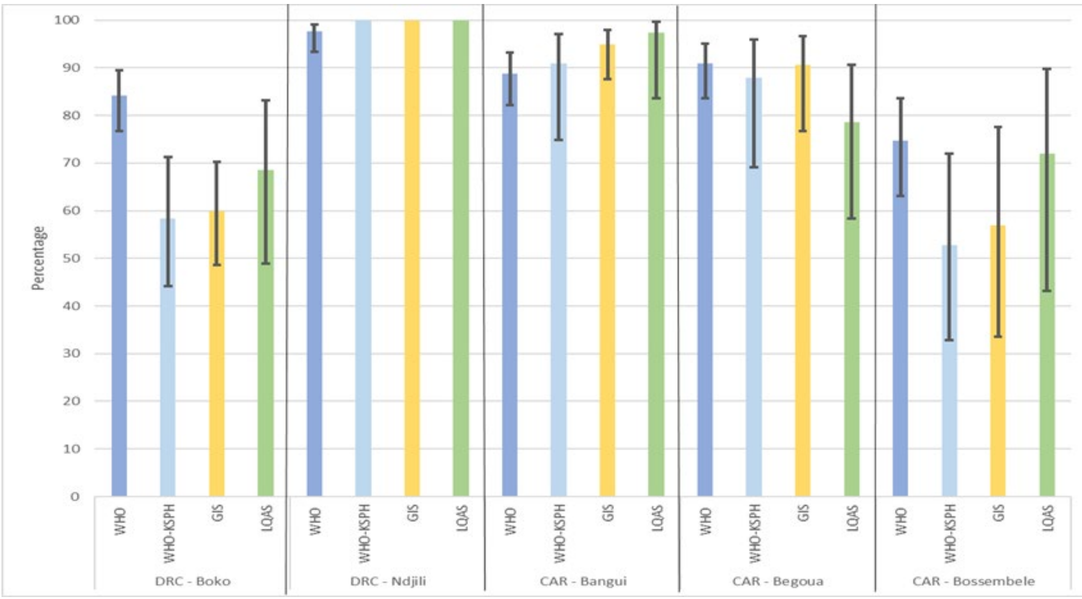

Figure 17: Percentage of BCG coverage among 6–11-month children by health zone and method

Overall, rural HZ/HDs in CAR and DRC had the lowest proportions of 6–11-month-olds vaccinated with Penta 1 for all methods (Figure 18). For example, in Bossembele, the proportion of children aged 6-11 months vaccinated with Penta 1 ranged from 37.8 % for the GIS method to 67.0% for the WHO method.

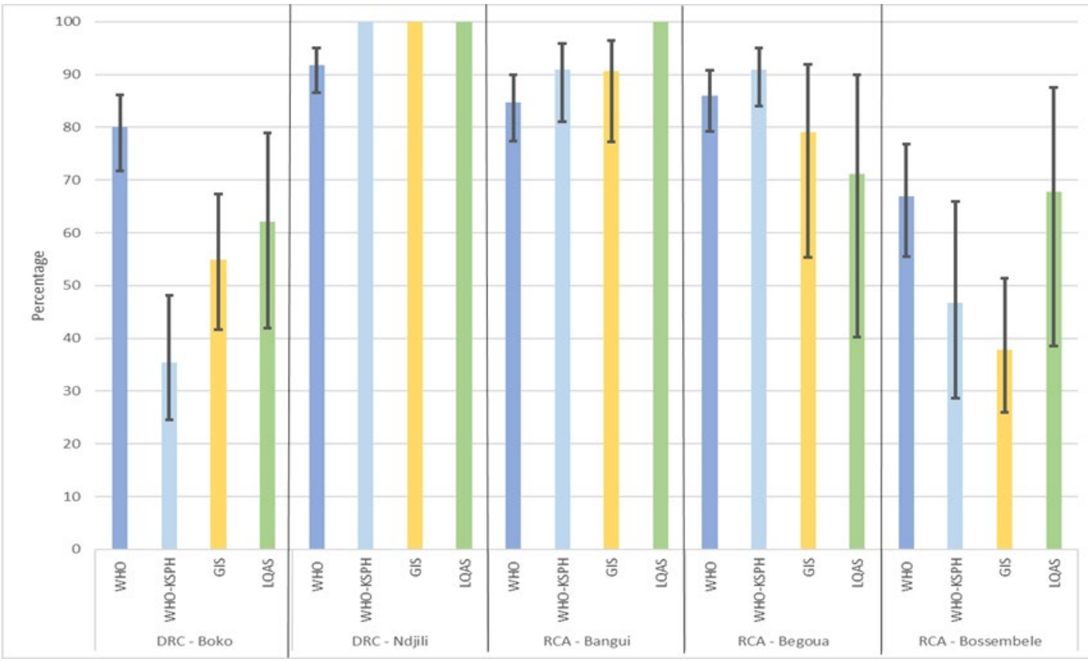

Figure 18: Estimates of Penta1 coverage among children aged 6-11 months by health zones and vaccine coverage assessment method

Reasons for Non-vaccination or Incomplete Vaccination of Children Aged 12 to 23 Months According to Mothers/Caregivers

The study also explored the reasons associated with non-immunization or under-immunization of children aged 12-23 months. The following section displays some of the most common reasons by method and by HZ/HD. Point estimates are reported without 95% CI. In general, the most common reasons for non-vaccination were that the vaccination site was too far away, that the mother was too busy, and family problems including mother's illness. Figures 19a, 19b, 19c report these reasons separately by method and by HZ/HD.

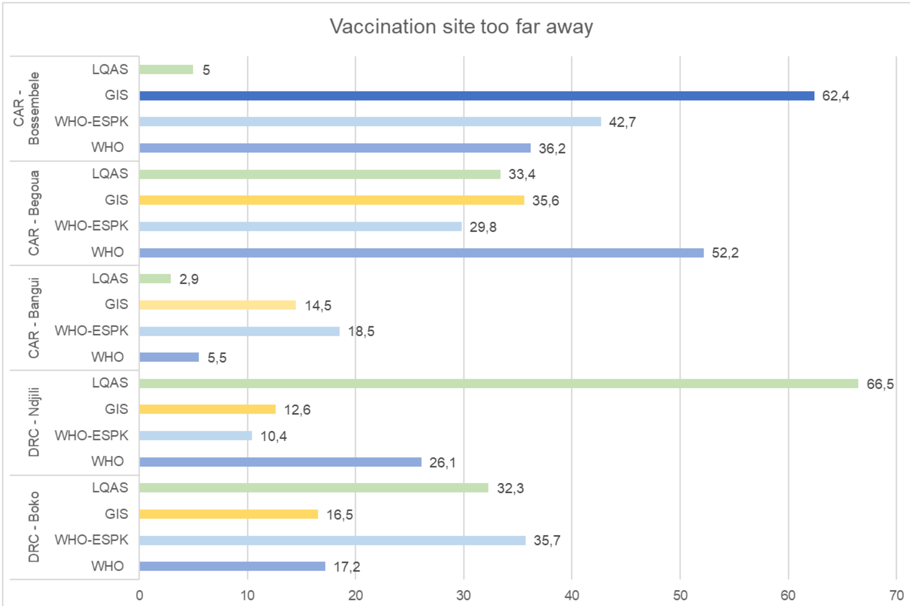

Figure 19a: Point Estimates of reasons for non-vaccination and under-vaccination of children aged 12-23 months in the health zones and methods for assessing vaccination coverage during VCS 2023 (Vaccination site too far away)

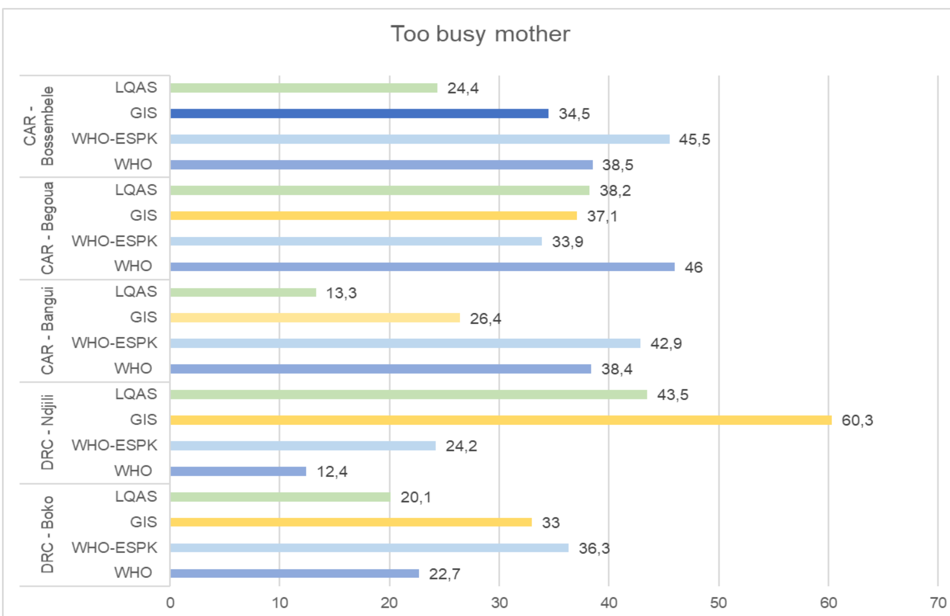

Figure 19b: Point estimates of reasons for non-vaccination and under-vaccination of children aged 12-23 months in the health zones and methods for assessing vaccination coverage during VCS 2023 (Mother too busy)

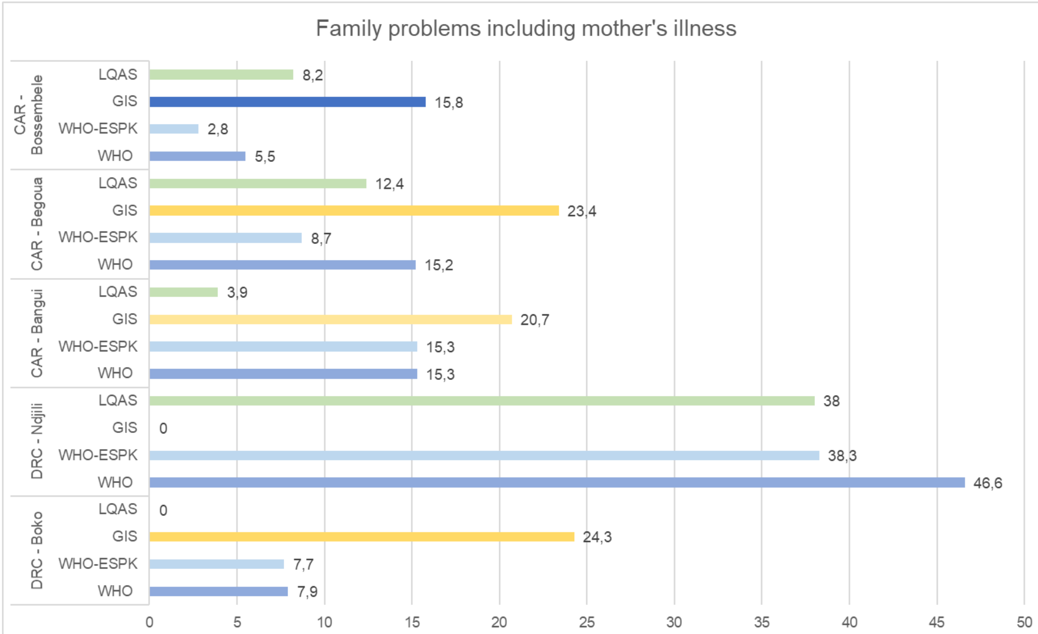

Figure 19c: Point estimates of reasons for non-vaccination and under-vaccination of children aged 12-23 months in the health zones by methods for assessing vaccination coverage during VCS 2023 (Family problems including mother's illness)

8.4. Vaccination Coverages Estimates: Simulations Varying Cluster Number by Method

As a part of this study, the number of clusters for the KSPH and GIS method were increased to allow for additional simulations in determining the amount of heterogeneity between clusters in the same HZ/HD. Simulations were also completed for the WHO and LQAS method as well. Finally, all clusters for each HZ/HD and method were put together to more closely look at variation at this level. The various graphics generated summarize simulation results.

Each pink figure on the left is an organ pipe plot (cite WHO 2018) that shows the variability in cluster-level outcomes within the district. Each column is a cluster as measured by the field teams. The shaded portion of the column represents fully vaccinated children and the unshaded portion represents children who were un- or under-vaccinated. Note that within each district the portion of children who were fully vaccinated varied substantially.

In these graphs, the vertical red line represents the estimated vaccine coverage on the x-axis, while the y-axis shows the number of clusters included in analysis. Coverage estimates and 95% CIs for each level are represented by the horizontal lines around the red bar. When the line is green, the estimated coverage falls within the inner 50% of the CI. When the line is red, the estimated coverage falls outside (either above or below) the CI. The length of these horizontal lines gives the confidence interval or precision. The graphs show that the precision of vaccine coverage estimates increases with the number of clusters, even as the cluster size decreases. The LQAS intervals are notable because so many of them are red and fall entirely above or entirely below the estimated coverage figure. This is a visual representation of the high variability of results from the LQAS design used here.

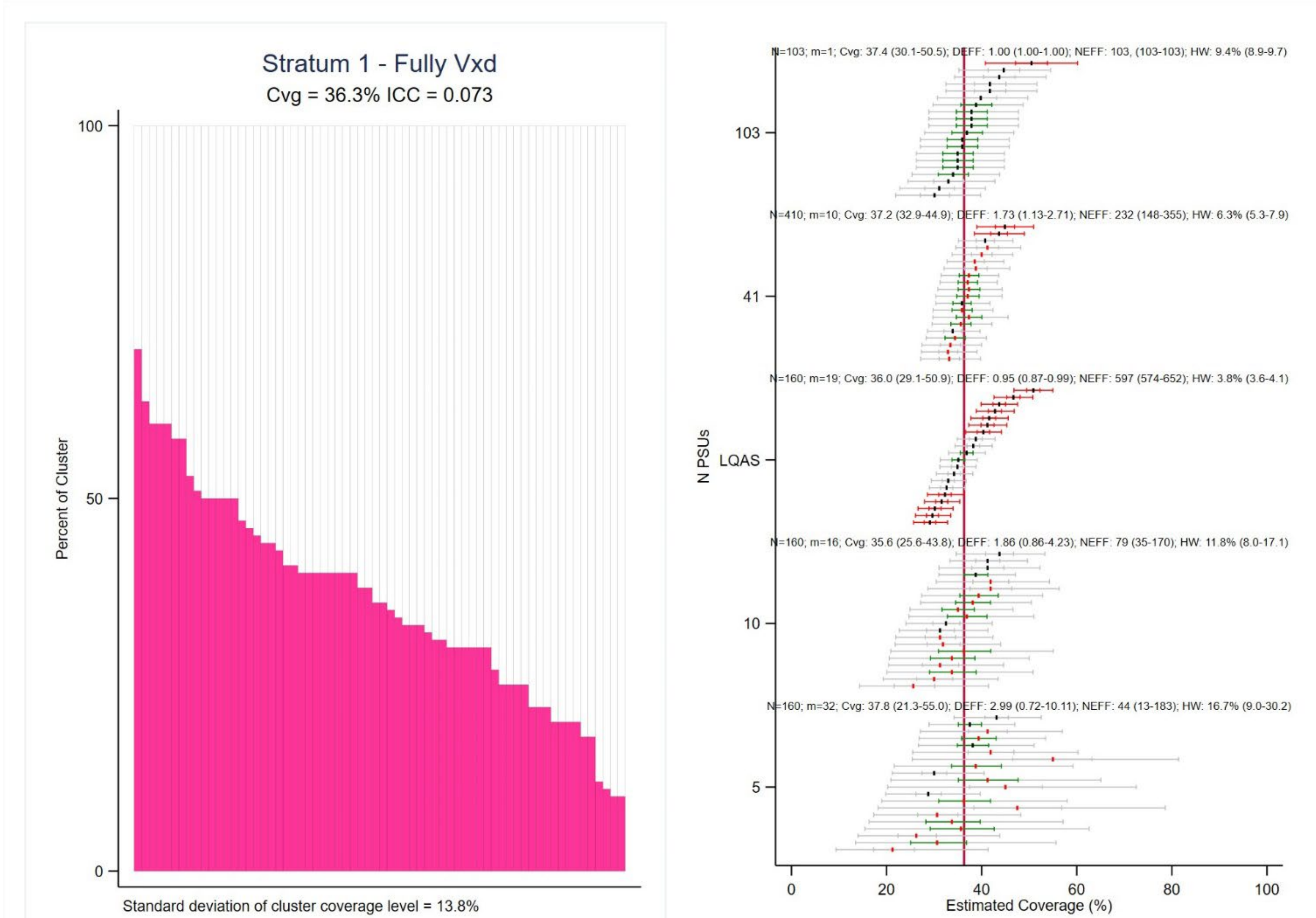

Figure 20a: Diagram of simulated numbers of households, clusters and "fully vaccinated" vaccine coverage for children aged 12-23 months in health zones with VCS 2023

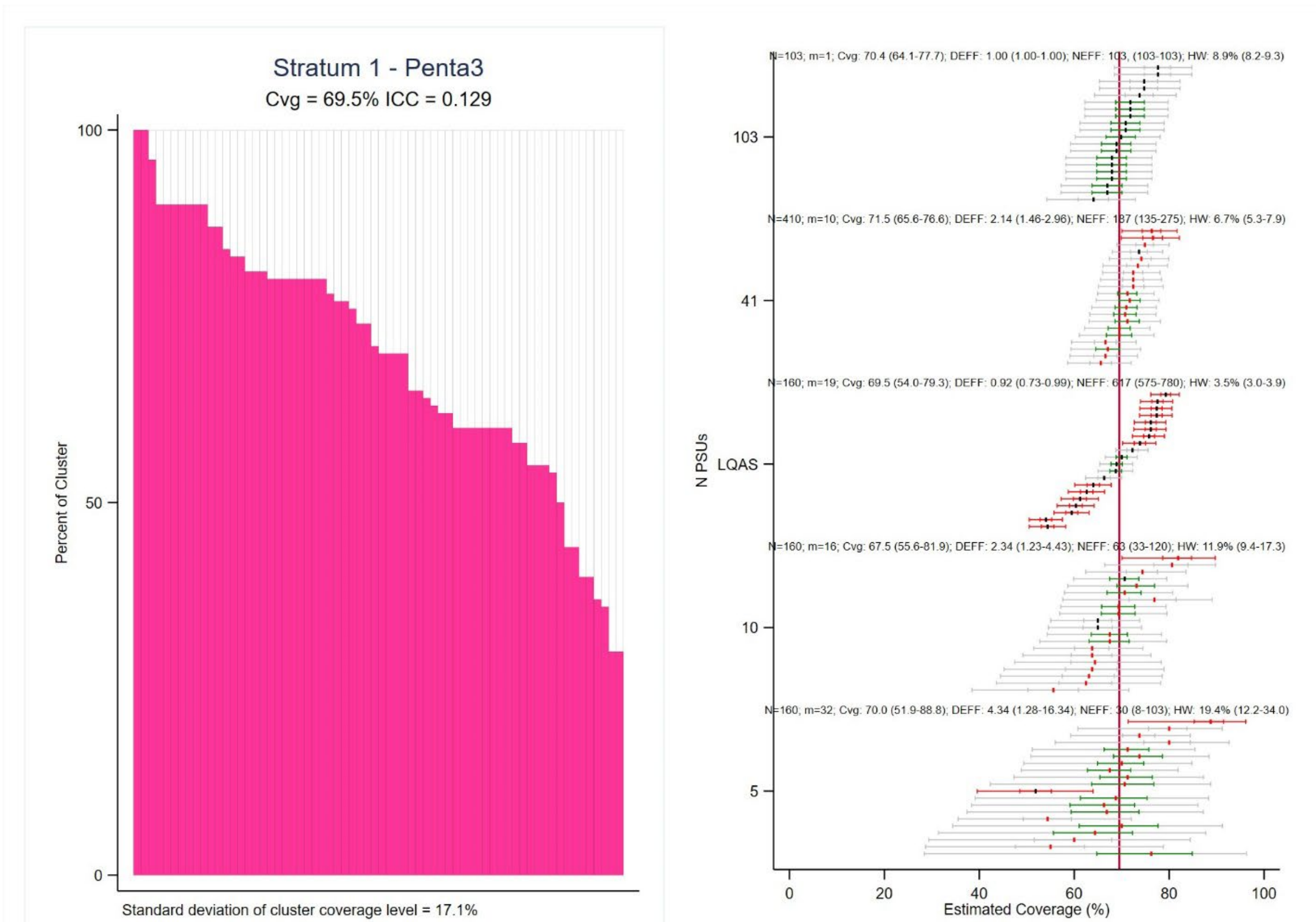

Figure 20b: Diagram of simulated numbers of households, clusters and Penta3 coverage for children aged 12-23 months in health zones with VCS 2023

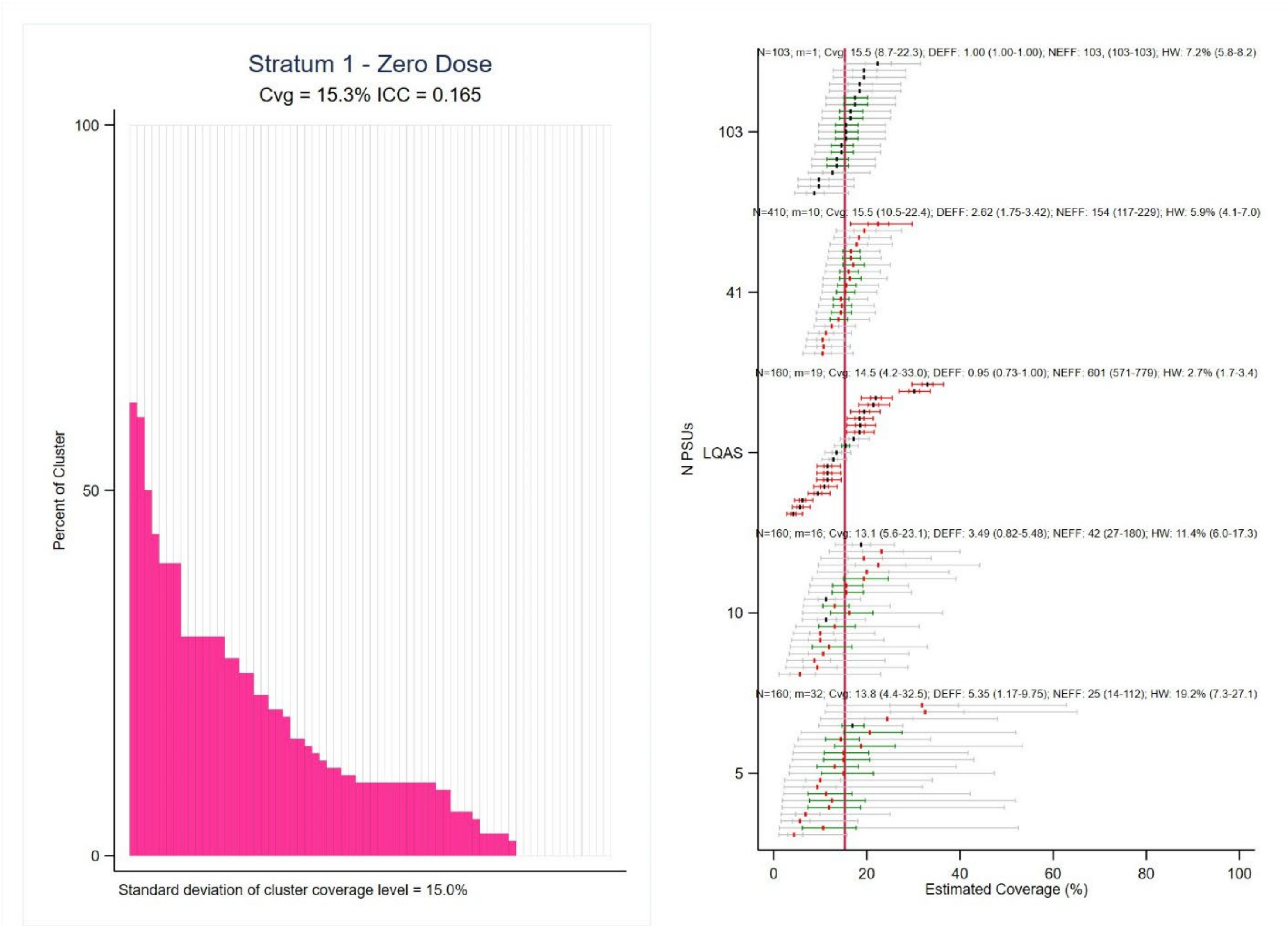

Figure 20c: Diagram of simulated numbers of households, clusters and "zero-dose" for children aged 12-23 months in health zones with VCS 2023 data

8.5. *Survey Results - Cost*

The comparative study of vaccine coverage methods also included a section devoted to a cost-effectiveness analysis of the various methods used (Protocol and full Report, Annex 1). This part of the study involved, firstly, identifying and measuring the effectiveness of different methods of estimating vaccine coverage; secondly, identifying and measuring the costs associated with these methods; thirdly, calculating a comparison ratio and, finally, carrying out a sensitivity analysis. The gold standard for this comparison was the WHO 2018-revised method.

Measuring the Effectiveness of Vaccine Coverage Methods

Vaccination coverage estimation methods involve collecting vaccination coverage data for each eligible child found in a household identified during the study. For this study, data was collected at household level. The eligible household surveyed was therefore the most important intermediate result for measuring the teams' work, since the number of children surveyed, and the estimate of vaccination coverage were determined by the number of eligible households surveyed (Table 14).

Table 14: Number of eligible households surveyed during the comparative study in the two countries, by site and by method

Health Zone/Health District	Method	Original		Adjusted	
		Clusters	Households	Clusters	Households
DRC-Boko	WHO	41	408	41	408
	WHO-KSPH	10	299	5	149
	GIS	9	306	5	152
	LQAS	5	87	5	87
DRC-Ndjili	WHO	41	418	41	418
	WHO-KSPH	10	299	5	149
	GIS	10	305	5	157
	LQAS	5	94	5	94
CAR-Bangui II	WHO	41	396	41	396
	WHO-KSPH	10	303	5	155
	GIS	10	302	5	151
	LQAS	5	95	5	95
CAR-Begoua	WHO	41	409	41	409
	WHO-KSPH	5	134	5	134
	GIS	5	150	5	150
	LQAS	5	96	5	96
CAR-Bossembele	WHO	41	381	41	381
	WHO-KSPH	10	336	5	170
	GIS	10	296	4	113
	LQAS	5	95	5	95
Total			**5209**		**3959**

In this study, the different teams involved surveyed different numbers of households (Table 14). N'djili teams using the WHO method surveyed 418 eligible households, while in Bangui II, they surveyed 396 eligible households. Teams using the LQAS method surveyed 87 households in Boko, 95 in Bossembele and 96 in Begoua. Generally, these numbers more or less reached the sample sizes expected in the different methods, if not the actual sample sizes or more houses than estimated. As with other activities, study implementation generates costs, which can be estimated. The following section presents the costs incurred during study implementation.

Calculation of Implementation Costs for Data Collection Methods

For this exercise, we used USD for all estimates. In DRC this is the standard currency used, while in CAR, the XAF is the standard currency used. During the study there were two different rates used (680 XAF= $1 in November to January and 600 XAF = $1 from February to July).

Overall, all costs incurred in the implementation of these methods can be presented in three scenarios: base case, without coordination costs, and adjusted for actual person-time. Base case costs demonstrate the actual cost of implementation of each method – what was spent on conducting the study. "Scenario 1" as presented adjusts for the cost of coordination teams – coordination costs were not the same in DRC and CAR as implementation in CAR required some additional support from the DRC/UCLA partnership. "Scenario 2" presents the costs incurred by method after both the removal of the coordination costs, as well as adjustments for person-time costs based on the actual time worked. Summary statistics for these three scenarios are presented as cost per cluster (Table 15) and cost per HZ/HD (Table 16) for each country in total, and for the entire study (overall).

Table 15: Summary of Costs incurred per cluster at the country-level by method for all costing scenarios

Country	**Scenario per Cluster**	**WHO**	**KSPH**	**GIS**	**LQAS**
DRC	Base case: As implemented	$924.24	$1,885.04	$1,859.39	$1,455.59
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$896.48	$1,718.94	$1,697.39	$1,351.09
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$218.58	$966.28	$968.28	$631.87
CAR	Base case: As implemented	$1,823.34	$3,215.08	$3,263.80	$2,639.23

	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,799.67	$3,074.95	$3,123.67	$2,550.29
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$297.28	$1,397.38	$1,439.38	$945.09
Overall	Base case: As implemented	$1,463.70	$2,623.95	$2,639.62	$2,165.77
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,438.39	$2,472.28	$2,489.77	$2,070.61
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$265.80	$1,205.78	$1,230.00	$819.80

Table 16: Summary of Costs incurred per HZ/HD at the country-level by method for all costing scenarios

Country	**Scenario per HZ/HD**	**WHO**	**KSPH**	**GIS**	**LQAS**
DRC	Base case: As implemented	$37,894.04	$18,850.43	$18,593.93	$7,277.95
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$36,755.54	$17,189.43	$16,973.93	$6,755.45
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$8,961.97	$9,662.81	$9,682.81	$3,159.34
CAR	Base case: As implemented	$112,135.37	$40,188.47	$40,797.47	$19,794.20
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$110,679.57	$38,436.87	$39,045.87	$19,127.20
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$18,282.97	$17,467.25	$17,992.25	$7,088.18
Overall	Base case: As implemented	$60,011.76	$23,615.56	$23,756.56	$10,828.86
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$58,974.04	$22,250.52	$22,407.92	$10,353.06
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$10,897.97	$10,852.02	$11,070.02	$4,099.01

During the implementation of the study, costs were incurred for the preparation of the training of the research teams, for the training of the research teams, for data collection in terms of field transport, field allowances, salaries, communication and supervision. Apart from these, costs were incurred for coordination, purchase of materials and data analysis. Direct costs were easy to allocate by method, while indirect costs were broken down using distribution keys based on team size (Table 17). As this was a pilot study, the coordination costs calculated are likely on the high extremes of what would typically be expected.

Table 17: Actual costs incurred during implementation of the comparative study in the two countries, by method [base cost, no adjustments for person-time]

DRC								
Line Item	**WHO**		**WHO-KSPH**		**GIS**		**LQAS**	
Supervision	$2,200.00	2.9%	$3,280.00	8.7%	$3,280.00	8.7%	$1,640.00	11.3%
Interviewers	$9,480.00	12.5%	$9,440.00	25.0%	$9,440.00	25.0%	$2,360.00	16.2%
Guides	$615.00	0.8%	$150.00	0.4%	$150.00	0.4%	$75.00	0.5%
Transportation	$3,640.00	4.8%	$3,800.00	10.1%	$3,800.00	10.1%	$1,200.00	8.2%
Communication	$440.00	0.6%	$720.00	1.9%	$720.00	1.9%	$280.00	1.9%
Equipment	$944.00	1.2%	$1,220.00	3.2%	$1,260.00	3.3%	$453.00	3.1%
Training	$2,674.93	3.5%	$3,735.62	9.9%	$3,735.62	9.9%	$1,260.68	8.7%
Coordination	$48,904.33	64.5%	$11,927.89	31.6%	$11,927.89	31.6%	$5,963.94	41.0%
Admin (10%)	$6,889.83	9.1%	$3,427.35	9.1%	$3,431.35	9.1%	$1,323.26	9.1%
TOTAL	**$75,788.09**		**$37,700.85**		**$37,744.85**		**$14,555.89**	
Cost per Cluster	$924.24		$1,885.04		$1,887.24		$1,455.59	
CAR								
Line Item	**WHO**		**WHO-KSPH**		**GIS**		**LQAS**	
Supervision	$3,400.00	1.5%	$4,080.00	5.1%	$4,080.00	5.0%	$2,520.00	6.4%
Interviewers	$14,880.00	6.6%	$11,840.00	14.7%	$11,840.00	14.5%	$3,680.00	9.3%
Guides	$1,025.00	0.5%	$200.00	0.2%	$200.00	0.2%	$125.00	0.3%
Transportation	$6,230.00	2.8%	$5,150.00	6.4%	$5,150.00	6.3%	$2,050.00	5.2%
Communication	$660.00	0.3%	$1,000.00	1.2%	$1,000.00	1.2%	$420.00	1.1%
Equipment	$7,593.00	3.4%	$8,894.50	11.1%	$9,944.50	12.2%	$3,481.50	8.8%
Training	$5,925.71	2.6%	$6,790.00	8.4%	$6,790.00	8.3%	$3,049.86	7.7%
Coordination	$154,172.93	68.5%	$31,335.96	39.0%	$31,335.96	38.4%	$18,801.58	47.5%

Admin (10% +3%)	$31,021.86	13.8%	$11,086.47	13.8%	$11,254.47	13.8%	$5,460.47	13.8%
TOTAL	**$224,908.51**		**$80,376.94**		**$81,594.94**		**$39,588.40**	
Cost per Cluster	$1,828.52		$3,215.08		$3,263.80		$2,639.23	

These overall costs were broken down by method-HZ/HD (Table 18) and also presented without coordination costs (Table 19) – which would likely provide lower estimates. Coordination costs included technical support for implementing the survey methodologies and may or may not be representative of a generalized experience – this cost can increase cost variation of study implementation and our study likely represents the lower end (DRC) and higher end (CAR) for coordination costs. For example, in CAR, the coordination cost not only includes the in-country support but also the support of UCLA and KSPH. However, in DRC for the standard VCS studies, the coordination costs consists only of KSPH support which further reduces the coordination costs of the national survey.

Table 18: Costs incurred during implementation adjusted for actual time worked of the comparative study in the two countries, by method and HZ/HD (in USD)

HD/HZ	WHO	WHO-KSPH	GIS	LQAS
DRC Ndjili	34,305.29	14,576.93	14,598.93	5,944.20
DRC Boko	39,205.79	19,801.93	19,348.93	7,566.70
CAR Bangui II	69,916.00	27,397.09	27,884.29	11,610.80
CAR Begoua	75,721.57	16,569.55	16,813.15	13,321.80
CAR Bossembele	75,721.57	32,907.09	33,394.29	13,321.80

Table 19: Costs incurred during implementation adjusted for actual time worked of the comparative study in the two countries, by method and HZ/HD without coordination costs (in USD)

HD/HZ	WHO	WHO-KSPH	GIS	LQAS
DRC Ndjili	6,734.47	7,287.81	7,307.81	2,421.84
DRC Boko	11,189.47	12,037.81	12,057.81	3,896.84
CAR Bangui II	8,793.47	11,083.80	11,503.80	3,742.12
CAR Begoua	13,886.24	8,016.90	8,226.90	5,217.12

CAR Bossembele	13,886.24	15,833.80	16,253.80	5,217.12

Typically, the WHO method had the highest costs overall, but the lowest costs per cluster while the LQAS method had the lowest costs(Table 20 and 21). In future studies we hope teams can use these calculations to help estimate costs for various methods (number of interviewers, transport, coordination, materials, etc.). We also noted that rural health zones (Boko, Begoua and Bossembele) had typically higher costs due to higher transport costs related to additional days of travel compared to those in the urban areas – where the team members returned to their houses daily.

Table 20: Costs per cluster incurred during implementation of the comparative study adjusted for actual time worked in the two countries, by method and HZ/HD with coordination costs (in USD)

HD/HZ	WHO	WHO-KSPH	GIS	LQAS
DRC Ndjili	836.71	1,457.69	1,459.89	1,188.84
DRC Boko	956.24	1,980.19	1,934.89	1,513.34
CAR Bangui II	1,705.27	2,739.71	2,788.43	2,322.16
CAR Begoua	1,846.87	3,313.91	3,362.63	2,664.36
CAR Bossembele	1,846.87	3,290.71	3,339.43	2,664.36

Table 21: Costs per cluster incurred during implementation of the comparative study adjusted for actual time worked in the two countries, by method and HZ/HD without coordination costs. (In USD)

HD/HZ	WHO	WHO-KSPH	GIS	LQAS
DRC Ndjili	164.26	728.78	730.78	484.37
DRC Boko	272.91	1,203.78	1,205.78	779.37
CAR Bangui II	214.47	1,108.38	1,150.38	748.42
CAR Begoua	338.69	1,603.38	1,645.38	1,043.42
CAR Bossembele	338.69	1,583.38	1,625.38	1,043.42

The cost for all of the survey methods were higher for CAR than DRC mostly due to the use of three coordination teams (CAR, DRC, USA). [2] The surveys in CAR required purchase of new tablets and additional security measures.

There were a number of factors that were varied including looking at the cost with and without coordination, valuation of donated tablets, and interviewer work time based on the amount they were contracted to work compared to the amount of time they actually worked. As they were contracted based on initial calculations, they could not be paid for fewer days – even if they completed the work in fewer days. A model spreadsheet can be accessed from Google for others trying to estimate survey costs. Overall, the WHO method was most expensive – but cheapest in terms of the per cluster cost, while LQAS was the least expensive.

It is important to note that there are important cost inputs that could be factored into a cost analysis depending upon study context. This include: air transport and excess baggage, costs for additional security – especially in areas that may not be controlled by the government or require special access, additional local transportation costs such as for boat rentals, excess fuel for extreme distances, taxes and road tolls, and special expenditures or external costs that are unable to have a receipt or justification. Thus, understanding cost drivers related to local context is important when planning surveys.

Sensitivity Analysis

As a part of the analysis, we varied costs of some factors – most notably the number of days worked. The actual costs were based on the contracts of interviewers and supervisors, regardless of the number of days worked, this is considered the base case, and includes all elements. This calculation was done by factoring the number of surveys expected per day (6) and travel time (Table 22). However, during the time analysis, we observed that often teams used less time that planned. We created scenario 1, which was updating the supervisor and interviewer costs based on what they worked. Finally, we observed that in this special case, the coordination costs were likely exaggerated compared to what real life costs would be for a larger country-wide survey. Thus we have also looked at the cluster cost without the coordination costs, this is represented by scenario 2. The % Change is also included.

Table 22: Sensitivity analysis (in USD)

Health Zone/ District	**Sensitivity**	**WHO**	**KSPH**	**GIS**	**LQAS**
DRC Ndjili	Base case: As implemented	$856.84	$1,578.69	$1,580.89	$1,265.84
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$836.71	$1,457.69	$1,459.89	$1,188.84
		2.3%	7.7%	7.7%	6.1%

[2] DRC had two coordination teams (DRC, USA) as the DRC has conducted multiple national VCS previously.

	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$164.26	$728.78	$730.78	$484.37
		80.8%	53.8%	53.8%	61.7%
DRC Boko	Base case: As implemented	$991.65	$2,191.39	$2,137.89	$1,645.34
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$956.24	$1,980.19	$1,934.89	$1,513.34
		3.6%	9.6%	9.5%	8.0%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$272.91	$1,203.78	$1,205.78	$779.37
		72.5%	45.1%	43.6%	52.6%
CAR Bangui II	Base case: As implemented	$1,726.49	$2,867.31	$2,916.03	$2,403.36
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,705.27	$2,739.71	$2,788.43	$2,322.16
		1.2%	4.5%	4.4%	3.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$214.47	$1,108.38	$1,150.38	$748.42
		87.6%	61.3%	60.5%	68.9%
CAR Begoua	Base case: As implemented	$1,871.77	$3,462.39	$3,511.11	$2,757.16
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,846.87	$3,313.91	$3,362.63	$2,664.36
		1.3%	4.3%	4.2%	3.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$338.69	$1,603.38	$1,645.38	$1,043.42
		81.9%	53.7%	53.1%	62.2%
CAR Bossembele	Base case: As implemented	$1,871.77	$3,439.19	$3,487.91	$2,757.16
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,846.87	$3,290.71	$3,339.43	$2,664.36
		1.3%	4.3%	4.3%	3.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$338.69	$1,583.38	$1,625.38	$1,043.42
		81.9%	54.0%	53.4%	62.2%

8.6. *Survey Results – Time*

As a part of the study implementation to compare methods, efforts were made to include time stamps (both automatic and confirmed by the interviewers) for steps before questionnaire collection and during questionnaire collection. A spreadsheet with additional calculations can be found in this Google spreadsheet. Before reaching the first house in a cluster, teams would complete a daily supervisor tracking sheet. This sheet included details on time the person left their house/lodging, time they spent at the HZ/HD coordination office (if needed), time they spent at health facilities, time they spent either locating a cluster, enumerating a cluster or identifying households in a cluster, and time to get to 1st house location. The exact variables depended on the method for each team. Once the team reached their households, and started a questionnaire, there was an automatic time stamp for the start of the questionnaire – which could be compared with when an interviewer said they the questionnaire. For this analysis, we used the start time of the questionnaires – and the end time was 1 minute before starting the next questionnaire, this would be considered time for a questionnaire and time for transport to next house. For the last questionnaire – one hour was added to the start time, based on the overall average of the other questionnaires for the whole study. For estimation purposes, one person from each method-HZ/HD team was randomly selected to explore their supervision questionnaire entries and household questionnaire entries. There was missing data – if there was missing information, it was treated as missing, not zero to not have an impact on the estimates.

Overall, the time components were broken down to: transport time (not taking into account time from coordination to HZ/HD – this was factored as 2 days for rural sites), administration time (time spent in administrative offices), cluster location/enumeration time, and questionnaire time (Figure 20).

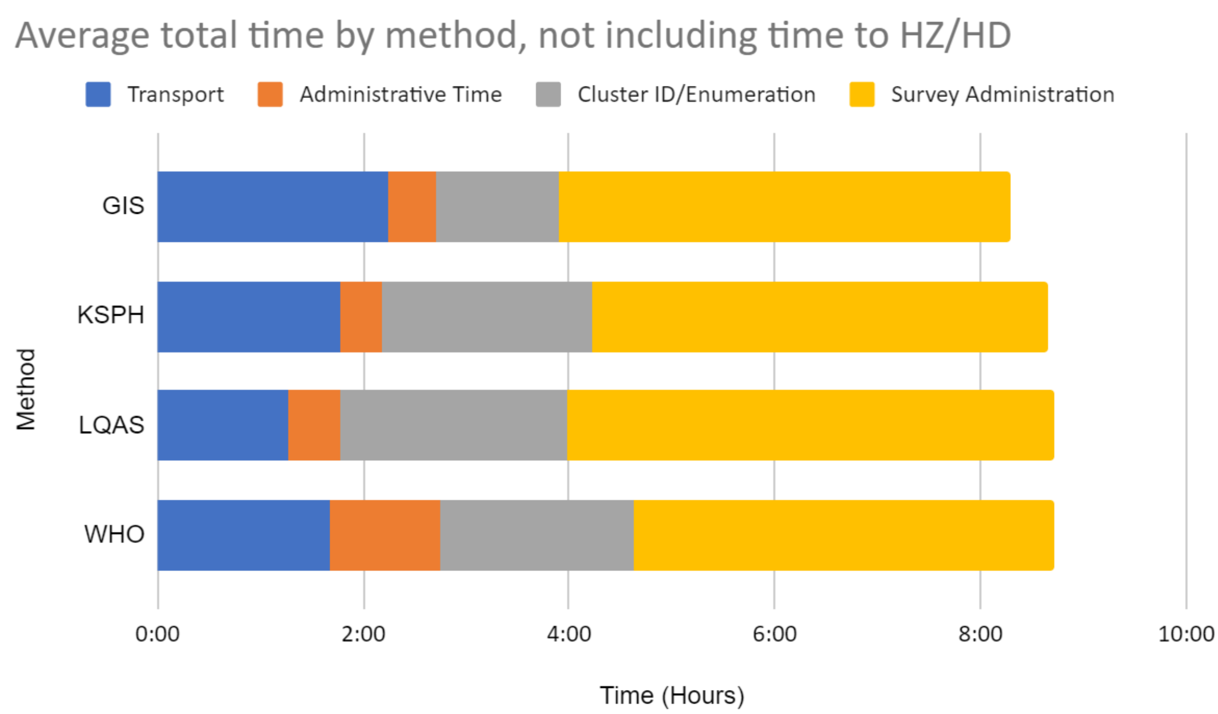

Figure 21. Mean time by method for study implementation when combining all sites.

On average, teams appear to work about 8 hours a day on average, with limited variation in time for questionnaire administration. The GIS teams had less enumeration/cluster location time, but more time in transport. The WHO team spent more time in administration time compared to the other methods. The KSPH and LQAS method had similar enumeration time experiences. When breaking these estimates down by HZ/HD and method, more variation is observed for transport time and administration time – which is expected between urban and rural location (Figure 22).

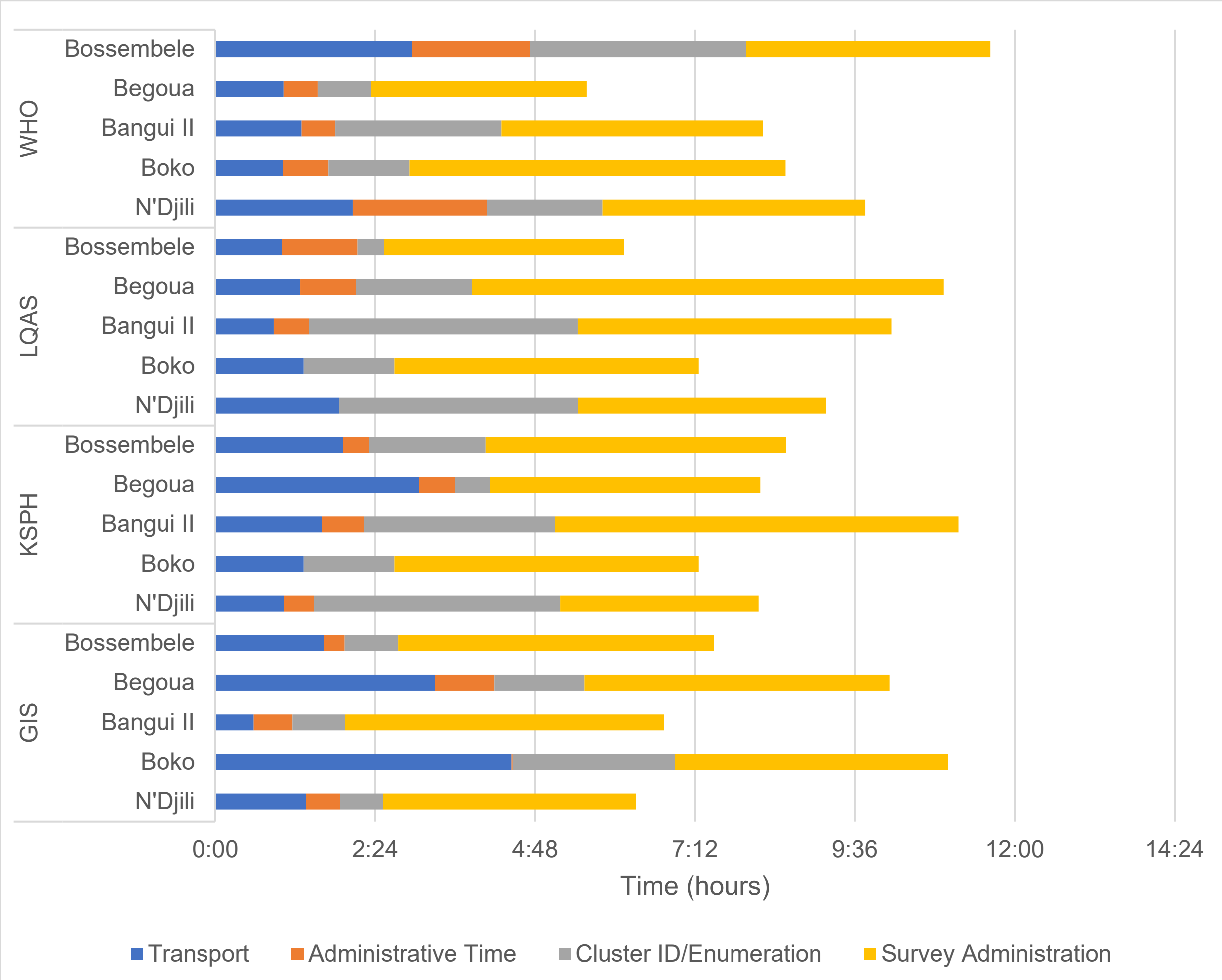

Figure 22. Mean time by method and HZ/HD for study implementation

Using the data from one person per HZ/HD method, we saw that on average it took similar amounts of time for the WHO, GIS and LQAS for survey completion, KSPH was longer on average – which may indicate longer distances between households, and the fact that the KSPH method had the fewest number of surveys on average completed a day. Further the time component on number of days worked, was as expected that WHO would take the longest – and was accounted for when planning the number of days. However, these estimates overall, indicate that there was more than sufficient time for study completion when using the planned number of days for setting study staff contracts for days worked.

Table 23. Time for survey completion, surveys per day and total days worked by method implementation

	WHO		KSPH		GIS		LQAS	
	mean	(min, max)	mean	min, max	mean	min, max	mean	min, max
Time per survey (minutes)	44	(33, 53)	77	(47, 113)	53	(35, 63)	57	(41, 75)
Surveys/day (no)	5.7	(4.3, 10.7)	3.5	(3.2, 4)	4.7	(3.7, 6.3)	4.5	2.9, 6.6)
Days worked (days)	11.4	(6, 14)	8.6	(7, 10)	7.2	(6, 10)	8	(5, 10)

9. Study Implementation and Team Experiences

This section will describe the experiences for each method collected during focus group interviews in each country and by method. Data also includes WhatsApp group coordination messages, coordination experiences in planning and carrying out data collection and other qualitative data. Additionally, during the meetings, data collectors were able make suggestions for improving the implementation of the study.

9.1. WHO Method

Role of Enumeration Areas and Household Enumeration

The WHO method required national census data in order to create enumeration areas (EA) with about 60 houses per EA in the HZ/HDs to select clusters. In the DRC, the National Institute for Statistics (INS) and in CAR, the Central African Institute for Statistics and Economic and Social Studies ICASEES) are responsible for managing census data. The most recent census in the DRC was in 1984, and thus EAs are obsolete, whereas in CAR, census mapping data are only a few years old (2021). As a result, EAs were defined differently in the two countries.

The CAR ICASEES provided the list of available EAs for selected HD. The CAR HD EAs, had maps but no accompanying population data and were larger than expected. Additionally, there were a huge number of EAs defined, however, especially in rural areas, many of these were empty. Thus, many additional EAs had to be selected to reach 41 clusters in the HD. After identifying each of the 41 EAs, teams were asked to enumerate 60 households to identify eligible households, from which 10 households were selected. This methodology was explained to the WHO teams. However, there was concerns on the difficulty of finding 60 households in rural areas using the current EAs.

“Because in rural areas it's difficult to find the 60 households, but in urban areas the method is clear" (N3, WHO, CAR).

In the DRC, the INS did not provide data in a timely manner so coordination team had to use other available data for the two selected HZs: N’djili and Boko. However, when trying to consolidate the EA data to the health zones in DRC, the coordination team identified that the N’djili EAs corresponded to neighborhoods, and thus contained more than 60 households. Thus, in DRC, a segmentation approach was used in which the HZs were segmented using vertical and horizontal levels into 64 EAs, from there 41 were selected at random. Of note, it is possible that this could lead to inconsistent weighting between the two countries. Teams were instructed to go through the political-administrative and health authorities to identify these segments, and then to enumerate 60 households before selecting 10 households. All team members in DRC WHO teams said this process was clearly explained to them.

The WHO teams indicated that they typically completed this process on the 1st day of the study, and after they were able to start implementation directly and not need to revisit the authorities’ multiple times.

"For me too, as the others have just said, it was very clear because the mapping had already been done at coordination level. The supervisor and we, the surveyors, had gone to the health zone to present the courtesies and then to get the other information as well as the people who could accompany us for the delimitation of each segment so that we could work well without overstepping our limits or boundaries. So, it was a very clear method" (P3, WHO, DRC).

For teams working in rural areas, the EAs could be comprised of several villages. Interviewers who worked in urban areas reported that enumerating 60 households was easy, especially where avenues were laid out and plots were often numbered. When teams were in large villages or several nearby villages, it was easy for teams to move around and total 60 households. However, for EAs that comprised of many small villages that were far part, it was necessary for the team to travel several kilometers – just for the enumeration – which then they had to do again to identify eligible households and then revisit selected households.

"It's like P7, P1 and P2 said earlier. We worked in a rural environment. It was very easy to find and count the 60 households in segments that were close together. But when you're dealing with a segment that contains several villages, and in those small villages there are small villages with 20 or 30 households, it's very complicated to count" (P6, WHO, DRC).

The difficulties are organizational, i.e., bringing remote villages together in the same AD. In some of the villages we worked in, two or three were grouped together in the same AD, and the team found it difficult to move around to count the 60 households" (N9, WHO, CAR).

Selection of Households

While WHO teams reported varying degrees of ease when implementing the program – especially noting differences between urban and rural areas – a common observation was the need to cover the entire Enumeration Area (EA) multiple times. In the enumeration process, identifying eligible households, and then returning for the interviews often led to back-and-forth travel within the EA. However, this did give the teams a good picture of the selected cluster. In urban areas, interviewers spoke of bands of "kuluna" (local gangs) posing difficulties covering certain health areas.

"What difficulties did we encounter in selecting households? Initially, there weren't really enough [households]. Households could be available. The only difficulty we had was that in some segments there were fewer households with eligible children, which made it a bit difficult to select, to first have the 10 households to work on. We were obliged to complete the survey in the nearest segments, and that was a difficulty" (P7, WHO, DRC).

Suggestions

In general, at the HZ/HD level, it was difficult to guarantee the 41 clusters needed for this method. While thought was given in DRC to use a segmented approach in lieu of not having recent census data, more thought would be needed to ensure consistent implementation at a country level to ensure accurate regional estimates. Additionally, for this method cluster selection is carried out at the HZ/HD level by the data collection team, and the coordination team must therefore be more confident of correct implementation, particularly for weighting after collection.

Several suggestions were proposed by the team members to improve the efficiency of this method and the survey in general. The main suggestion (across all method teams) was extending the time of the data collection – however, on review of data collection times, the coordination teams typically saw that most teams not only completed data collection within the allotted time, but finished earlier than planned. In planning the number of days of work, travel time and survey completion of 6 surveys per day was used as a benchmark for days of work.

"Take into account the cost of transport and allow more time for collection, and review ADs at ICASEES level" (N8, CAR, WHO)

Some interviewers suggested separating the enumeration from the data collection itself, possibly by dividing the team into different sub-groups. They felt that this would allow the data collection team to already have an idea of the presence of eligible households before coming to a community. While others suggested reducing the enumeration to fewer than 60 households, as they felt the time available for study operations was reduced by having this extensive enumeration step.

9.2. WHO-KSPH Modified Method

Cluster Identification

For the WHO-KSPH modified method, health areas (HA) were used as the cluster level. In the DRC, the HAs are well defined entities in the health system and were obtained from the National Health Information System -the DHIS2. However, in CAR, there is currently not a well-defined HA entity within defined HDs, thus, the coordination team used positions of health centers within the HDs to create health area divisions.

The cluster selection in each HZ/HD was then completed by the coordination team. A random list of preselected HAs with alternate clusters was given to the collection teams along with an explanation on how to implement along with the further segmentation of the HAs. However, in cases where alternate clusters needed to be selected, this may have been completed in the field by the collection team. Once teams arrived in the administrative and HZ/HD offices, they were instructed to determine if there were any areas with major security concerns – as these would necessitate selecting alternate clusters. As such, the coordination team needs to ensure they have high confidence in the collection team for correct implementation, particularly for weighting after collection.

The coordination team was also able to provide the collection team maps using Flowminder and M4H data with villages, roads, waterways and landmarks for most selected HAs. Collection teams were instructed to use these or, when not available, hand-drawn maps to further segment the HA. The collection team was instructed to work with their local guides to navigate the HAs and selected segments. Of note, some team members indicated that HZ/HD staff did not always have a good understanding of the cartography, which complicated cluster identification for the teams.

"... and what's worse, some health facility managers don't know their area of jurisdiction and this poses a problem during the investigation" (N7, ESP, RCA).

Cluster Segmentation

Once teams confirmed the location and security of selected clusters (HAs), they were instructed to segment the HA into 16 segments using a grid method. Team members reported that the HA segmentation methodology was easy and clear to them. During training, information on the method was provided as well as the segments to choose (along with alternatives), so all they had to do was confirm the HA map and apply the segmentation procedure. Some team members who relied on needing maps at the HA area reported that sometimes there was no official map available or that sometimes someone else who was unavailable was in charge of the maps. Some team members noted that segmentation could be made difficult by the shape of certain health areas or the shape of certain maps. For some team members, the difficulty was not in segmenting but in reaching certain segments because of the absence of roads or the inaccessibility of sites.

> *"I said that the method was very clear, because it was easy to apply in the field. The segmentation, the plot survey, the choice of target households, in any case we didn't have too many problems applying everything we'd been taught" (P9, ESP, DRC).*

> *"The protocol is very clear, but in the field we had difficulties locating the segment" (N9, ESP, RCA).*

> *"Because if we have to segment a card according to the segmentation method we were taught, it is often difficult for the shape of certain cards" (N8, ESP, RCA).*

When possible, teams were given available maps by the coordination team, however, some members indicated that the segmentation procedure was easier in the field as almost all the nurses had maps of the health area where they worked, which were often clearer and more up-to-date than the maps the coordination had provided. This was the case when there were new HA subdivisions which were not yet on coordination-provided maps. This information was also useful for segments with especially difficult terrain or those which were completely inaccessible, segments that were empty with no population or in urban segments which may be dangerous due to gangs. Most team members said information received from the nurses was all the information they needed to identify, locate and access the segments once the segmentation was completed.

> *"The segmentation, as the others said, was easy, it wasn't that difficult...when we tried to do it with the school mapping, we were still able to target the village as the methodology recommends" (P9, ESP, DRC).*

Locating Segments in Cluster and Identifying Households

All team members were unanimous in stating that locating the selected segments was very easy. This ease was due to the fact that the segmentation was carried out in the presence of the local nurse with locally available maps. After segmentation was completed, the team members would tell the nurse which segments had been pre-selected, and the nurse would provide all the information needed to locate and access them. Further, the team used the local guides – often community volunteers or village chiefs -- to help navigate to selected segments.

> *"To locate the segment, I'd say it wasn't difficult. It was easy to locate a segment, because already when you do the segmentation and you tell IT: here are our target segments, they are such and such, it already explains to you that in this segment, we want to take two or three villages, for example, and then it explains to you which one is very accessible, which one is inaccessible". (P3, ESP, DRC)*

> *"I think everything's already been said... it was easy and all you have to do after the segmentation is explain to the IT or the guide, the chosen segment is theirs as it's their map, all we had to do was segment it, and they could easily find the streets where you could go to work. So, it was easy" (P5, ESP, RDC).*

Once teams were in the segment, they were instructed to enumerate the households in the segment, and then were instructed to select 5 from each segment – for a total of 30 houses per cluster.

Suggestions

A primary suggestion was that while maps were provided by the coordination team, they preferred using maps supplied by the local nurses. This allowed them to use the map with the most accurate information on the clusters. The team members suggested additional time to work with local guides for better household sensitization prior to enrollment. The majority of team members suggested removing the household enumeration and going straight to interviewing as soon as a household had been identified, claiming that enumerating households in order to have 18 eligible households took too much time and often meant that when the interviewers returned for interviews the respondents were no longer present in the households.

While some teams were able to have clearly defined segments for data collection, many clusters in all HZ/HDs did not follow the prescribed 5 households interviewed in each segment, nor were they always clearly defined. During the weighting process, the segments were not included as a level in the weighting scheme, as this would have provided additional confidence in the weighting and output smaller confidence intervals.

9.3. GIS Method

Identification of and Navigation to Location of GIS Points and Buffers

The GIS method used a gridded methodology which allowed clusters to be selected by coordination team. The GIS points were generated at the coordination level by an expert in cartography. A code was written in R – thus R programming skills were needed, however, in CAR – ArcGIS was also used. GPS points were randomly generated based on satellite information on the population with concentric circles around them. This method allowed for additional level of checks at the coordination level after data collection to ensure that teams reached the cluster and followed the correct procedures. In order to implement this method, accurate maps and GPS data are required for cluster selection, which may not yet be available in many low and middle-income country contexts.

The selected GIS points were superimposed on detailed printed village maps with roads, waterway and landmark information to aid in location. Additionally, the GIS team had access to an additional application, outside of the SurveyCTO, called "SW Maps" to aid in navigation. This added an extra program for this team to use and added additional tablet time – which had to be accounted for in areas with poor electricity. At the start of data collection, the teams were required to have internet access to upload mapping images; once uploaded, internet was not needed for the navigation application. Collection teams also used the help of local health authorities to identify the selected clusters. Once teams entered the selected cluster, they followed the procedures outlined by the coordination team for identifying households.

Team members were divided on the ease of finding clusters and using an additional application. Those who had worked in an urban environment, said that the protocol was clear and easy to apply, and that they had no difficulty using the application to locate GIS points and concentric circles. They also reported that once the application had been launched and the locations recorded, it worked smoothly even when offline. Team members in rural areas almost universally stated the opposite. For them, the location protocol was unclear due to a number of difficulties. The first difficulty was that the map used as a reference was not always up to date. Participants reported having to locate GIS points that should be in a village, when in reality either the village was very far from the point, very small, did not have the name indicated, or was not known to the local authorities or guide. The second difficulty in using the application was that the maps didn't show road layouts or geographical obstacles, so teams often found themselves having to cross rivers or reach places that were inaccessible due to a lack of roads.

> *"For me, the GIS method was really very clear. Good! I don't know about those of us who had worked in Kinshasa, but it didn't pose much of a problem for us. As*

soon as you open it, you can see how you're already moving around until you reach the little GIS points" (P2, GIS, DRC).

"And those who were in the health zone weren't able to identify which village was here or which point we had to pass through. That's the big problem. We need to update this GIS method" (P7, GIS, DRC).

Some team members pointed out that sometimes the GIS point was in a large concession or an uninhabited school, where there were no households. Others reported that sometimes, it was important to have an internet network for the maps and locations to update more quickly, a difficult situation when teams were in rural areas.

"As we often found ourselves in areas where there was no network coverage, we didn't always know how to update the map easily, so we had to drag our feet a bit to wait for the map to update, which took a few minutes, but the application itself had no problem. It's easy. (P1, GIS, RDC)

Others reported difficulties in using the mapping application on the tablet as security issues (presence of "Kuluna") prevented them from taking out the tablet to orient themselves. But despite this, all respondents were unanimous in saying that their experience of the SW Maps application and in general navigation to clusters was good, as it guided teams directly to the locations, at least geographical ones, where they needed to collect data.

"In particular, not to repeat what others have said, my experience is that the application is already good, and in the field I had no difficulty in reaching the GIS point. Nevertheless, I also had no difficulty in getting within a few meters of the GIS point, because we weren't exactly at zero meters from the GIS point, but sometimes we got within 6 meters of the GIS point, because the GIS point was sometimes in a concession, in a plot of land. It's difficult to enter a plot of land with the tablet in hand to try and get to the GIS point" (P4, GIS, RDC).

"As soon as the application is launched even if the tablet is in old mode application continues to geo-locate your position." (N5, GIS, RCA)

During data analysis, it was noted that in Bossembele HD/CAR, only four clusters were correctly identified and surveyed even though the team went to 10 clusters. During further interviews, the team did not identify any reason for this and indicated they thought they had gone to the correct clusters. Thus, for analysis, these six clusters were excluded as weighing data was not available, and only data from the four correct clusters was weighted and presented in the analysis. During simulations, average weights from the four clusters were used. Additionally, one cluster in Boko HZ/DRC was identified after collection as being in another HZ – Kenge --which shares a border with Boko. This cluster was excluded from the analysis, and only nine clusters were included for Boko. This cluster was not included in any sensitivity analysis.

Navigation Time to Locate GIS Points and Buffer

The majority of respondents stated that the time needed to locate the GIS point and navigate the buffer circle depended first and foremost on the environment and then on the team's location in relation to the point to be reached. In urban environments, distances were short and the availability of means of transport made time very short. In rural areas, on the other hand, it was possible to travel several kilometers, for several hours at a time, to reach a point. Participants who had worked in rural areas added that factors such as road availability, and weather issues could also have an effect on the time to reach a GIS point. However, all team members agreed that, once the GIS point was reached, it was very easy to navigate the buffer circle.

> *"We can already say that the time already depended on where you were in relation to the point you wanted to reach. Let's take the example of the people of N'djili, we who were here in N'djili usually met up in district 1. Already, if we have a point that's not very far from district 1, we can make it in less minutes than a point that's far towards district 13 in N'djili; already there you have to take motorcycles" (P6, GIS, RDC).*

> *"In any case, for us who were in the Boko health zone, if we located a certain GIS point from a starting point, leaving that starting point for the arrival point could sometimes take us a whole day. There were points we had to locate in the morning, but we got there in the evening" (P3, GIS, DRC).*

> *"Very time consuming the time it took to locate each GIS point it depends in relation to our distance but in households it varies between 15 to 20 minutes." (N12, GIS, RCA)*

> *"Not very time-consuming as soon as we arrive in the area the GIS point is quickly found unless the point is not in the forest or bush" (N3, GIS, RCA).*

Household Identification in the Buffer Areas

Some team members said that in some clusters it was difficult to have 30 eligible households in the 1st buffer area - making it difficult to reach enumeration targets. However, larger buffer areas were also provided to the teams to help in these instances.

> *"With regard to specific difficulties, especially in terms of logistics, the kits are incomplete, as the GIS points are often in the bush, which requires protective*

footwear and a raincoat, and the other difficulty is visibility: we are mistaken for vaccination officers, which prevents some parents from receiving us properly, i.e., participating in the study" (N3, GIS, CAR).

Suggestions

Team members discussed the need for improvements in terms of power supply. As an additional application was used and power was not always available, teams suggested solar panels as a secondary power source. Some teams were provided with additional funds for fuel for generator use to aid in charging tablets. Team members also stressed the need to have up-to-date maps with cluster selection on in inhabited areas.

"We need to generate points in populated areas. Review the logistics of the rolling stock and the appropriate kits." (N3, GIS, RCA).

9.4. LQAS Method

Selection of Supervisory Areas

The LQAS method had the fewest implementation requirements for cluster selection of the four methods. This method uses a batch selection process that is carried out at the HZ/HD by the data collection team. The method relied on collection teams to divide the health zone into a supervision axis or an enumeration and analysis zone and does not require specific population estimates for weighting. In standard practice, this method has been intended more for classification purposes and involves a small number of batches and participants. Much wider confidence intervals are typically expected at the health zone level. But when batches are aggregated at provincial or district level, they can provide an accurate estimate, similar to the other methods. This could be improved by increasing the number of batches per enumeration area.

Collection teams were trained to determine the number of supervisory axes and the number of health areas in each supervisory axis from the Central Health Zone Office (BCZS) when contacting the health authorities. A procedure was written for the random selection of a health area in each supervisory axis, up to 5 clusters. The team was then instructed to enumerate and sample households. Under the current health zone conditions, the data on the supervisory axes were supplied to the coordinator, who drew the health areas using random number generation applications.

All team members reported that the identification of supervision axes and areas were very easy. This ease was due to the availability of data on HZ/HD activities and mapping. This was provided by the study coordinator or the health zones when the teams arrived. The teams also relied on the support of local nurses and guides.

> *"I think it was easy because before entering each health area, we should first see...consult the head doctor of the health zone. He received us and sent us to IT to get the mapping. Once we had the cartography, it made it easier for us to work well" (P3, RDC, LQAS).*

Team members raised the problem of replacing health areas in the LQAS method. They said that the coordinating team had not informed them to prioritize the replacement health areas. When they requested such, they found themselves in places without telephone coverage. This made activities difficult or required the use of other time-consuming means.

Locating the First Household in Cluster

In general, team members had no difficulty locating eligible households and identifying 19 eligible households. They noted that in some cases, they had to cover two or more avenues or villages to get to the 19 eligible households. If the number of eligible households at the end of the enumeration exceeded 19 households, they withdrew households to be surveyed. A number of respondents pointed out that they had used nurses and community relays to facilitate these field activities.

The majority of participants reported that identifying the first household in the cluster was easy. However, this task's ease was contingent upon another step: the enumeration of households at the avenue or village level. As such, the enumeration was considered an additional step that could either facilitate or complicate the identification of the first household, depending on the specific structure of the cluster.

> *"Finding the first household as soon as we had already located the avenue with the support of the community relays, we had to switch to our method, counting, enumerating. As we progressed, we easily identified the target households... It wasn't really difficult to find the household there because we knew from the first enumeration work that there was a household in such and such a family at such and such an address" (P1, RDC, LQAS).*

Suggestions

To improve the implementation of the LQAS method, most team members suggested eliminating the enumeration stage, so that data can be collected directly as soon as an eligible household is identified. One member, however, pointed out that enumeration is a requirement of the method in order to have a sample and enable analysis.

Others wished that the alternative health areas had already been identified ahead of time. This would avoid having to go back to the coordinator in the event of a problem or need to choose an alternate. Often once the teams were in the field, there was limited ability to communicate with the coordination team. A final suggestion for the team was the retention of local guides, as they provided significant support for enumeration and data collection.

> *"There are guides who know the villages and they even know that in such and such a village there are so many children who are part of our target. And when you list the households, you really find that these are the numbers they told you. I think that's what I can suggest as a way of improving the LQAS method" (P4, DRC).*

9.5. Overall Study Experiences

While four sampling strategies were used: WHO method, KSPH method, GIS method and LQAS method, the survey tools used were the same for every method. The team members and coordinators identified a number of points for the household portion of the survey during their discussion. The primary difficulties identified were: finding people at home, age of eligible children, availability of vaccination information, length of questionnaire and what to do when the same households were selected for multiple methods.

Availability of Respondents

Team members reported that, in general, the time needed to carry out a household visit depended on the respondent's availability, level of understanding, and readiness to provide the vaccination card. Additionally, some team members indicated that respondents often did their daily tasks at the same time, which could not only influence the time for the survey but also the concentration to provide accurate responses during the survey. One of the main concerns posed by the team members was the general availability of the respondent. They often had to come very early before respondents would go to the field, or in the evening when they returned. Thus, teams often reported that they had atypical work hours for data collection. Additionally, as enumeration was often separate from the final selection, some households may have been available during the enumeration but were not available during the survey – meaning that the team had to select other households.

Eligibility of Children (Age)

Some team members also indicated that they had difficulties with identification of children or their age – to ensure that they were within the eligible age category. Participants said that often, when meeting someone other than the mother or primary caregiver, the age given to the child was not accurate. This could lead the team member to start the questionnaire, and find out after some time that the child was actually not eligible which would disrupt the enumeration process.

> *"You are told that the child is six months old when you arrive to take the survey. By then, you've already drawn the sample and assigned the numbers in relation to the household number requested. Then you arrive and realize, together with the mother, that the child is only 5 months old and therefore ineligible. That's when everything gets turned upside down, including the very order in which households are allocated. Numbers from 1 to 19 also pose a problem. We'll have to go back to the survey, the enumeration, the enumeration where we can also find another child who will replace the one you had who wasn't eligible. That was also a major difficulty in the field" (P1, DRC)*.

Questionnaire Length

Most team members reported that the visit itself was not very time-consuming. In the best of cases, the interview took around 45-50 minutes with a respondent who had a good level of education, good knowledge of vaccination and the child's vaccination card. The interview took longer when comprehension was difficult, when translation was required, or when the mother/caregiver did not have their child's card.

> *"Well, I'd say it was pretty time-consuming. It depended, as some of my friends said. If the mother already had a vaccination card, we didn't drag our feet because the information we were looking for was already in the vaccination card, but if you came across a household where the mother didn't have a vaccination card, it took time because the mother had to be able to remember the vaccination dates.*
>
> *"Sometimes, when you're talking to a mother, she can leave you for other concerns, and I can see that it's not always very time-consuming to visit each household" (N1, KSPH, CAR).*

Some team members indicated that respondents often complained, especially as they said they always had things to do, such as going to the fields in the morning and preparing food in the afternoon. Additionally, if the families were large or there were multiple children, the survey could take much longer to complete.

> *"The duration of the survey in a household depends on the number of eligible children in the household; if there are more children, the duration also increases" (N8, WHO, CAR).*

One suggestion from a team member was that additional filters should be included in order to shorten the interview for those who refuse vaccination or have in general no accounts of vaccination.

> *"But I think that the questionnaire should also introduce the notion of a filter if you arrive in a household like that which is targeted but the child is not vaccinated. I think that in principle, as the survey is based on vaccination coverage, the interview for this type of household should stop there. But we could see that the questionnaire was still going on, and we were obliged to answer it right to the end" (P4, DRC).*

Due to general comprehension of participants, some team members indicated that especially in rural areas, there was a lack of understanding. Some respondents did not always give accurate accounts of vaccination services, due to the presence of local guides who may also be involved in vaccination services.

> *"We had the impression at times that when we were evaluating, when we wanted answers about the quality of the vaccination service offered in the facilities, they weren't telling us the truth because the fact that the guide is there made them think that there were some who admitted, who said that if I told the truth that when we come with the children we leave them standing, there isn't even a bench to sit on, we risk being arrested. Some of them sent us this. We got the impression that some of them were giving answers to satisfy the guide who was there, maybe that wasn't the real answer they wanted to give. That was perhaps the difficulty". (P4, DRC)*

> *"I think it depended on the mother you were dealing with, it depended on the person first of all, and then it also depended on what documents the person had. When the person doesn't have the documents, even if they've studied, you have to start by explaining the OPV too. That's how you talk about everything when you give the OPV, so that the person understands, even if they're an intellectual, you still don't master everything. I think it was ...for me .....it depends" (P3, LQAS, DRC)*

Availability of Vaccination Information

While the vaccination data collection was part of the survey, there were some elements that were specific to vaccination data – either on cards, guardian recall or information at the health facility. Some respondents indicated they had not vaccinated their children because health care providers were charging 3,000 to 5,000 Congolese Francs, and suggested that the Ministry of Health should make vaccination cards free. For those who did have vaccination cards, some teams had issues in some areas where the respondent would refuse to let the team member take a picture of the card, or the respondent was bothered by neighbors asking why they were letting team members take pictures of a personal information. During the consent process, the respondents were informed of all procedures including that a picture would be taken of the child's vaccination card if available.

> *"I'd forgotten about it, but fortunately P5 had brought it up, although not all the women did, but I could still see the expression on their faces when it came to taking the photo. Even though we explained to mom or dad that we were going to capture the card, it wasn't going to do anything, but many weren't really cooperative" (P4, DRC, WHO)*.

Some team members noted that while families had vaccination cards, they were either blank or incorrectly completed – including missing vaccines, which sometimes parents would insist their child had received. In addition, there was often the need to work with multiple people in order to complete the vaccination portion of the survey.

> *"At times, it was difficult to really interact only with the respondent, because it was like a curiosity event: the father was there, maybe if the mother-in-law was there, everyone was talking about the child and so on. So, at times, the respondent was even silent, saying that my mother-in-law is sitting down when she's there, so I can't express myself in front of her, so we couldn't rush them or force them, because there are certain habits" (P4, DRC)*

Some team members noted difficulty in finding information at facility level in the event of mother's declaration of immunization data, and some providers would not provide information immediately, instead asking interviewers to return days later. Additionally, when they did have access to the records, there were sometimes discrepancies in ages and names of children, which led to some confusion.

Duplicate Households

A final difficulty was that the coordination team made the decision that even if overlapping clusters were selected for different methods, these selected households should be approached as initially selected. This led to about 70 households in the two countries being selected for participation more than once through different methods. While attempts were made to explain that this was a possibility to participants, not all households were willing to participate or they would complain that they had already completed this study. This likely would not be an issue on a larger country wide survey with just one survey methodology used.

10. Discussion

The purpose of this study was to compare multiple vaccine coverage survey (VCS) methodologies to the gold-standard WHO cluster survey method. We chose three additional approaches for comparison: WHO-KSPH modified method, GIS method and LQAS method. While there are many other coverage survey methodologies that could have been included, these three were specifically chosen for their recent use in other LMIC settings, including the recent nationwide VCS in DRC using the WHO-KSPH modified approach. Major differences between the methods included the number of clusters selected, number of children included per cluster, cluster selection, and for the inclusion of a household enumeration step. The overall outcome of each method was a vaccine coverage (VC) estimate at the health zone/district level with corresponding confidence intervals. The survey tools used and consent procedure for each method was identical; the only variation between methods was the sampling strategy. In addition to coverage estimates and precision, we also assessed time, cost and individual experiences for each methodology.

For most of the results, we considered the WHO method as the "Gold Standard" for comparison. Overall, findings indicate that the WHO method was the most precise, longest to implement and most costly when compared to the other three methods. While not as precise in coverage estimations, the other three methods were successful in that they produced comparable results, and were applicable in both urban and rural settings. Additionally, when examining the 95% CIs of each HZ/HD and method, most overlap with one another. However, there are some outliers, specifically in Boko and Bossembele. The overall precision of the WHO method was expected at the HZ/HD level. However, in practice it is unlikely that this method would be applied nationwide. Instead, the implementation of the WHO method would typically be at the country or province/regional level. However, using the experiences of the DRC, both national leadership and immunization partners have indicated that having additional information at the HZ level is important. This will ensure that every health zone is represented in the provincial estimates.

The KSPH method has been the standard implemented study design for the VCSs since 2021. The results indicate that the LQAS method was the quickest and least expensive to implement. It required the least amount of staff time and transport as it has the fewest households per cluster (~95). However, the estimates for many of the indicators measured by the LQAS method generally had the widest CIs. The KSPH and GIS methods required almost the same amount of time in terms of workload and approximately the same cost to implement. In general, the KSPH method estimates were more precise than the GIS method estimates, but this varied by location. The GIS method relied on the clusters selected at the coordination level, which required accurate geographical information on population distribution. However, these pre-selected clusters then relied on teams to be able to accurately navigate to the areas, and that selected villages themselves had not changed location. Some GIS teams found that once arriving in a cluster, that there were very few inhabitants or that the starting points were inaccessible areas. For the KSPH method, the collection teams themselves were left to segment selected health areas and select clusters. Based on the GIS method results, this was not always implemented the same across study teams.

While some HZ may be more homogenous in vaccine coverage, this should not be the expectation for all 519 HZ of the DRC, which may lead to significant variation in coverage estimates (large confidence intervals). Further, when looking at results from the simulations, it shows that even with cluster numbers between 5 and 10, coverage estimates and 95% CI overlap with the vaccine coverage found, but it may not be adequate enough to estimate with high accuracy HZ/HD level outcomes due to the heterogeneity found within the strata. In the DRC, most provinces have at least 11 or more health zones. Consequently, when the 5 clusters per health zone are aggregated to the provincial level, there is usually a very large number of clusters - ranging between 55 and 175. This exceeds the standard estimated number of clusters needed per province according to the WHO method. Results in the final ECV documents are presented at the province rather than HZ level. This should be a consideration for other countries in determining the optimal methodology and sampling frame for accurate coverage estimates that can be integrated into the WHO WUNEIC yearly estimates. For example, in CAR, there are 7 regions and only 35 total HDs -this would already indicate that there may need to be additional considerations when selecting the study methodology.

Compared with simple random sampling of households in each cluster, the methods in comparison are subject to estimation variability and pocket effects, such as the tendency of nearby households to share the same vaccination status. However, these differences are not considered very significant in practice, given that national and sub-national VCS are generally designed with a margin of error of 5-10%.

Each of the four methods employed probability sampling in which each eligible household has a known, non-zero probability of being selected. However, for the GIS method, the probability of household selection was unknown a priori; but it was approximated a posteriori based on the method that enough households were visited to reach 30 households with a child aged 6 to 23 months per buffer point. The WHO method required census data for sampling proportional to the population. Such data, if it exists, is often outdated or erroneous in resource-limited countries. By avoiding cluster selection through census-based population proportional sampling, the sampling used in the other methods in comparison was not subject to potential biases caused by inaccurate or out-of-date census data. Instead, they relied on the organization of the healthcare system and the alternative definition of clusters.

This report presents the vaccine coverage and other indicator findings, costs, time, and experiences for implementing each method. Overall, there were a number of strengths and limitations identified.

10.1. Strengths

This study has led to a rich dataset from two different LMIC settings. This study provided a unique opportunity to create a South-South-North collaboration bringing together two Central African countries (DRC and CAR) and one Northern country (USA). This collaboration was driven by the Kinshasa School of Public Health (DRC); the Ministry of Health and Population and the Department of Public Health of the University of Bangui (CAR), ICASEES and the University of California Los Angeles (UCLA-USA). This collaboration allowed each partner to demonstrate their experience and expertise as well as creating a multidisciplinary team that enabled us to achieve high quality results. Most notably the exchange of technical committee members in each country for a collaborative effort. To foster this collaboration, three technical teams were set up, one for the DRC, one for the CAR, with the support of UCLA for both as well as an external committee with members from many partner organizations for additional input. All project activities from conception to implementation were discussed, decided and organized by these technical teams in a collaborative effort. As a result, the coordination team was able to develop a single protocol approved by three different ethics committees: USA (UCLA), DRC (KSPH) and CAR (Université de Bangui). In addition, the protocol was shared with the DRC and CAR steering committees (Expanded Program on Immunization and partners) and external reviewers including the Bill and Melinda Gates Foundation (BMGF), WHO, UNICEF and GAVI, each providing feedback which was integrated into the final protocol.

In the design of the study, the decision was made that implementation in each country would be simultaneous – which meant that training for all methods was done at the same time, and no team members could be a part of multiple teams. Additionally, most of the training was for the whole collection team together – with only individual training sessions on the sampling methodology. This helped to ensure that the consent procedure and data collection in the household and health facility would be more consistent. By implementing all methods simultaneously, there was a reduced risk that collection teams would improve as they moved through methods. However, this did require that there were more people trained. Additionally, the DRC implemented the study first as they have had 3 years of experience in the VCS implementation, and the CAR team spent 10 days in DRC to participate in all aspects of training and implementation. To add further transparency, the CAR team was responsible for reviewing and ranking DRC collection team candidates and vice-versa. This process also was shared with external partners. For the CAR training, the DRC team, with UCLA, went to Bangui to participate. Additionally, during implementation, one DRC team member remained in CAR to help oversee data collection.

The collection teams were successful in implementing each method in the selected HZ/HDs in both DRC and CAR. Data was collected from over 5,000 children 6-23 months, of which over 80% had vaccination cards. Additionally, the teams collected data on each cluster including timed data. During administration, each of the teams' costs were kept separate when possible to help with cost effectiveness analysis. At the end of collection, there were additional focus groups and qualitative data review in order to understand better the experiences of each team, as well as to note suggestions for future study implementation. Thus, while this was primarily a VCS survey, these additional elements allowed for many additional future analyses. One example is that the typical WHO-KSPH method collects data from 5 clusters per HZ, but in order to allow for additional simulations post collection, the team increased most sites to 10 HZ for both the KSPH method and GIS method. We also collected time-stamped data on entering vaccination cards in the field as well as entering vaccination cards at the central level to compare the differences – the results of this are not included as a part of this report. In general, this protocol, dataset and report will be a rich source of information for future studies.

Finally, one of the proposed outcomes of this study was to provide wider guidance on potential strengths and weaknesses of multiple methods in comparison to the WHO cluster survey method that was revised in 2018. CAR is planning to implement a national VCS before the end of 2023. The results of this study will help inform the coordination team and partners on the final methodological decision for implementation. Additionally, there are now 96 data collectors in Bangui that have been trained in implementation and data collection, hopefully increasing capacity for the future national survey implementation.

10.2. Limitations

While this study has provided a rich source of data for future studies, there are a number of limitations which should be noted.

As this was a pilot study, only a small number of HZ/HD were selected, and this selection was not completely random. In order to have as much oversight as possible by the coordination team, HZ/HD were selected based on their proximity to the coordination site (Kinshasa in DRC and Bangui in CAR). However, this selection process did attempt to find representative areas and cover both urban and rural locations. There were 2 HZ of 519 in DRC and 3 HD of 35 in CAR. However, the results by method were also combined to form a "Practice Region/Province." The goal was to mimic what would typically happen in practice for nationwide VCS.

While all attempts were made to implement the methods the same in each country, there were some differences. For the WHO method, the DRC lacked recent census data, making enumeration areas inaccurate. As a result, each health zone was divided into 64 segments. Whereas in CAR, there was recent census data with acceptable information on the EAs to be used for the WHO method implementation. For the KSPH method, samples are typically drawn at the health area level. However, this level does not exist in CAR. Therefore, using the location of health facilities within the 3 HDs, the coordination team created areas that were similar to the well-defined HAs in DRC. Additionally, when looking at spatial collection of the segments, this was not applied consistently – with more deviations on 5 houses/6 segments in CAR observed. For the GIS method, both countries' maps had discrepancies. For example, in DRC, there were two boundaries for Boko HZ which led to one cluster being excluded during analysis as it was later determined that it was not actually located in the selected HZ. LQAS was the only method which had defined supervision axes that were likely similarly identified.

The DRC has conducted 3 nationwide VCSs since 2021. Thus, the DRC team had a different level of experience – which also extended to the collection teams. When selecting collection teams, most members of the DRC team had already participated in a number of surveys – including the most recent 2023 VCS. They had also all had extensive training on vaccination information and tablet usage, and most were involved in health activities. In CAR, there have been fewer national surveys, and the data collection team was largely made up of demographers and statisticians with limited experience of this type of data collection. This may have led to differences in general site collection and data collection between the two countries. For example, in Bossembele HD, 6 GIS clusters were excluded from the analysis as the teams were unable to correctly identify the clusters – and instead collected data in other areas. In Bangui II HD, for the WHO method, instead of labeling each cluster (1-41), the team instead used the day number to identify all clusters sampled on that day (1-15), so clusters had to be recreated using GPS data by the coordination team after the fact. However, there are now over 85 potential data collectors that have participated in this experience in CAR, which may be useful for their upcoming national survey.

Many focus group members identified that they had difficulty taking photos of vaccination cards. Images of the vaccination cards were included as part of the survey for additional analysis which included entering the card data coordination level and comparing this information with the field entry. The field teams reported that some children's parents or guardians did not consent to photos of the cards, and that the quality of the image for data capture of the cards at central level was no better than that for direct data capture in the field. Thus, while data entry at a central level may be more consistent, there would be more missing cards or if photos were not taken of the right area – less data available. There were many cards in the field that were not correctly completed, yet, with field entry, teams could discuss these missing data points with the respondents.

A priori primary data used to build the weighting schema contained its own methodological limitations. These limitations should be considered when interpreting coverage estimates presented in this report. When possible, we used techniques that would have led to wider confidence intervals to account for this uncertainty.

While this study was not free of limitations, many of these are also learning experiences which can be used to better select, train and plan for future studies.

11. Recommendations and Conclusion

The coordination team generally concludes that the selection of a methodology for a national VCS should hinge on the primary objective and the resources available for implementation. For example, in the DRC, implementing the WHO method as prescribed would necessitate a substantial nationwide effort to delineate enumeration areas—a challenging task given the outdated census information. Thus, the DRC adapted to modify the WHO method in order to align with the structure of the health system to facilitate optimal implementation. This study has demonstrated that with thoughtful planning and implementation of varied study methodologies, all are viable and valid options.

However, the interpretation of the results at some levels should be cautious, and account for the uncertainty and potential variability of point estimates. In the DRC, there are 519 HZ – and no province has less than 10 HZ- thus estimates for the WHO WUENIC at the province level are likely more accurate than the individual HZ estimates. These HZ estimates are typically used more for a general benchmark of the operational level. In a small county or country with a different health system structure or different primary objectives, the sampling strategy may be different. However, each step should be documented and well described for preparation of the results but also for improving future studies.

The study team enrolled the help of local technical coordination teams in both countries and external experts to review the protocol and proposed methodologies. They also worked with experts in biostatistics and cost analysis as well as engaging with WHO and other partners. This type of partnership is important to discuss how to strengthen the overall study designs of each method. As these studies are often not only benchmarks for the country to assess their progress in vaccine coverage, but also generate estimates used by partners and help adjust administrative vaccine coverage estimates (which are typically overestimates), they are incredibly valuable activities. Thus, the role of the external partners in this work remains a major element to ensure strong collaborations and wide acceptance of results produced.

Each method described in this study was found to be valid when compared to the WHO method, with limitations to be contextualized in the planning of national VCSs. However, it would not be recommended to use the results of the other method at the HZ/HD level, without a number of limitations as to what can be interpreted. These indicators should be more of a general idea of the vaccination coverage in the HZ/HD. This includes classifying whether there is generally low coverage, or inequitable distribution of vaccines in the area, or high coverage. However, these results at a higher aggregated level such as the province in DRC or the region in CAR would be much stronger and ensure that there is coverage information from every HZ/HD as opposed to only selecting clusters from the higher level.

Ultimately, this pilot vaccine coverage survey in DRC and CAR was designed to compare alternative methods of estimating immunization coverage in a low-resource context. Each method – WHO, KSPH, GIS or LQAS – had both its strengths and weaknesses when comparing the precision, cost, and time of the generated estimates. For example, the WHO method, as implemented by our team, had the most precise results, yet of all methods selected was the costliest and time consuming. However, the WHO 2018 revised VCS allows for increased flexibility in designing coverage surveys and can be adapted with these alternative methods as guides for future surveys. This means that many of the methods that were used in this study are in line with suggestions from the revised WHO manual. However, as these are suggestions, some researchers may find them difficult to visualize to reality. We hope this report can serve as a guide for implementation and modifications.

12. References

1. Soofi SB. Third Party Verification Immunization Coverage Survey (TPVICS): The Aga Khan University; 2021.
2. Hussain I, Khan A, Rhoda DA, Ahmed I, Umer M, Ansari U, et al. Routine Immunization Coverage and Immunization Card Retention in Pakistan: Results From a Cross-sectional National Survey. Pediatr Infect Dis J. 2023 Mar 1;42(3):260-70.
3. UNICEF WHOW. Burkina Faso: WHO and UNICEF estimates of immunization coverage - 2020 Revision; 2021.
4. (WHO) WHO. Vaccines and Immunization. Health Topics 2024 [cited 2024; Available from: https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1
5. (WHO) WHO. Immunization Agenda 2030; 2021.
6. Ye Y, Wamukoya M, Ezeh A, Emina JB, Sankoh O. Health and demographic surveillance systems: a step towards full civil registration and vital statistics system in sub-Sahara Africa? BMC Public Health. 2012 Sep 5;12:741.
7. Linard C, Tatem AJ. Large-scale spatial population databases in infectious disease research. Int J Health Geogr. 2012 Mar 20;11:7.
8. GRID3. Population Estimates in the Democratic Republic of the Congo draw on one of the largest survey efforts in almost 40 years. 2022 [cited 2024; Available from: https://grid3.org/news/popestimates-drc-survey
9. Generale ID. La RCA en chiffres : résultats du recensement général de la population et de l'habitation, Décembre 2003; 2005.
10. (WHO) WHO. World Health Organization Vaccination Coverage Cluster Surveys: Reference Manual; 2018. Report No.: WHO/IVB/18.09.
11. USAID. DHS Methodology. The DHS Program: Demographic and Health Survey 2024 [cited 2024; Available from: https://dhsprogram.com/Methodology/Survey-Types/DHS-Methodology.cfm
12. UNICEF. MICS Surveys. 2024.
13. Kok PW. Cluster sampling for immunization coverage. Soc Sci Med. 1986;22(7):781-3.
14. D. L. ENQUÊTE DE COUVERTURE VACCINALE CHEZ LES ENFANTS DE 6-23 MOIS En RÉPUBLIQUE DÉMOCRATIQUE DU CONGO. University of Kinshasa School of Public Health; 2021.
15. ICASEES. MICS6-RCA Enquête par grappes à indicateurs multiples 2018-2019; 2021.
16. Gass K, Deming M, Bougma R, Drabo F, Tukahebwa EM, Mkwanda S, et al. A Multicountry Comparison of Three Coverage Evaluation Survey Sampling Methodologies for Neglected Tropical Diseases. Am J Trop Med Hyg. 2020 Oct;103(4):1700-10.
17. Sandiford P. Lot quality assurance sampling for monitoring immunization programmes: cost-efficient or quick and dirty? Health Policy Plan. 1993 Sep;8(3):217-23.
18. Gong W, Taighoon Shah M, Firdous S, Jarrett BA, Moulton LH, Moss WJ, et al. Comparison of three rapid household survey sampling methods for vaccination coverage assessment in a peri-urban setting in Pakistan. Int J Epidemiol. 2019 Apr 1;48(2):583-95.
19. Boo G, Darin E, Thomson DR, Tatem AJ. A grid-based sample design framework for household surveys. Gates Open Res. 2020;4:13.

20. Singh J, Jain DC, Sharma RS, Verghese T. Evaluation of immunization coverage by lot quality assurance sampling compared with 30-cluster sampling in a primary health centre in India. Bull World Health Organ. 1996;74(3):269-74.
21. Jutand M, Salamon R. [Lot quality assurance sampling: methods and applications in public health]. Rev Epidemiol Sante Publique. 2000 Aug;48(4):401-8.
22. Milligan P, Njie A, Bennett S. Comparison of two cluster sampling methods for health surveys in developing countries. Int J Epidemiol. 2004 Jun;33(3):469-76.
23. Turner AG, Magnani RJ, Shuaib M. A not quite as quick but much cleaner alternative to the Expanded Programme on Immunization (EPI) Cluster Survey design. Int J Epidemiol. 1996 Feb;25(1):198-203.

13. Appendix 1: Additional Vaccine Coverage tables

Vaccination coverage of children aged 12-23 months by two combined sources for all antigens in the pilot study by HZ/HD and method in DRC and CAR, 2023

Antigen	Health zone/Health district	WHO			WHO-KSPH			GIS			LQAS		
		n	%	CI 95%	n	%	CI 95%	n	%	CI 95%	n	%	CI 95%
Full coverage	DRC - Boko	249	32.7	[25.8-40.5]	89	15.0	[7.9-26.7]	94	32.6	[11.7-63.8]	52	35.7	[18.7-57.4]
	DRC - Ndjili	255	59.3	[52.4-65.9]	90	64.3	[43.6-80.7]	84	77.7	[62.2-88.1]	58	52.6	[44.3-60.8]
	CAR - Bangui II	245	44.8	[38.5-51.3]	106	43.8	[35.7-52.2]	81	56.2	[45.5-66.4]	55	52.2	[40.4-63.7]
	CAR - Begoua	272	38.6	[31.1-46.7]	91	60.9	[50.4-70.4]	94	15.5	[8.6-26.4]	61	19.6	[10.6-33.4]
	CAR - Bossembele*	261	14.6	[9.5-21.7]	90	6.7	[2.2-18.9]	65	6.2	[2.3-15.3]	59	26.6	[13.1-46.5]
BCG	DRC - Boko	249	83.8	[77.7-88.4]	89	52.3	[40.2-64.2]	94	74.6	[52.7-88.5]	52	64.4	[41.6-82.1]
	DRC - Ndjili	255	97.3	[94.0-98.8]	90	97,0	[92.3-98.9]	84	100.0		58	97.3	[81.9-99.7]
	CAR - Bangui II	245	85.0	[79.7-89.1]	106	94.0	[82.3-98.1]	81	93.0	[78.3-98.0]	55	92.2	[73.8-98.0]
	CAR - Begoua	272	84.5	[79.3-88.5]	91	97.6	[89.4-99.5]	94	80.7	[74.2-85.9]	61	78.0	[67.9-85.6]
	CAR - Bossembele	261	58.3	[49.7-66.5]	90	48.6	[34.0-63.4]	65	53.4	[35.4-70.6]	59	85.4	[62.6-95.3]
VPO_0	DRC - Boko	249	92.5	[87.0-95.8]	89	89.3	[72.8-96.3]	94	94,0	[74.6-98.8]	52	87.7	[64.7-96.5]
	DRC - Ndjili	255	100.0		90	100.0		84	98.3	[88.6-99.8]	58	100.0	
	CAR - Bangui II	245	96.9	[92.6-98.7]	106	98.8	[91.2-99.9]	81	95.5	[89.5-98.1]	55	100.0	
	CAR - Begoua	272	99.2	[96.7-99.8]	91	98.8	[93.4-99.8]	94	98.2	[89.6-99.7]	61	90,0	[70.5-97.2]
	CAR - Bossembele	261	86.9	[77.2-92.8]	90	76,0	[56.2-88.6]	65	96.2	[73.9-99.6]	59	97.1	[78.4-99.7]
VPO_1	DRC - Boko	249	75.8	[68.6-81.7]	89	51.6	[38.8-64.2]	94	74.5	[51.0-89.1]	52	57.4	[30.9-80.2]
	DRC - Ndjili	255	86.8	[81.8-90.6]	90	92.5	[82.5-97.0]	84	100,0		58	95.1	[83.4-98.7]
	CAR - Bangui II	245	80.5	[74.4-85.3]	106	90.1	[79.5-95.5]	81	92.1	[86.3-95.5]	55	83.7	[71.2-91.4]
	CAR - Begoua	272	80,0	[74.3-84.6]	91	92.2	[78.9-97.4]	94	76.5	[68.5-83.0]	61	75.5	[59.8-86.4]
	CAR - Bossembele	261	50,0	[41.7-58.3]	90	47.5	[32.8-62.5]	65	41.9	[24.4-61.6]	59	90.5	[75.8-96.6]
VPO_2	DRC - Boko	249	66.3	[58.7-73.2]	89	32.7	[23.0-44.1]	94	68.2	[43.4-85.7]	52	50.5	[26.7-74.1]
	DRC - Ndjili	255	86.0	[81.0-89.9]	90	91.7	[81.2-96.6]	84	100.0		58	95.1	[83.4-98.7]
	CAR - Bangui II	245	75.3	[68.7-80.8]	106	84.4	[71.5-92.1]	81	85.7	[75.2-92.2]	55	82.8	[71.3-90.3]
	CAR - Begoua	272	71.8	[65.3-77.5]	91	86.4	[67.9-95.0]	94	71,0	[63.9-77.2]	61	60.8	[45.3-74.5]
	CAR - Bossembele	261	41,0	[33.4-49.0]	90	28.3	[20.7-37.3]	65	35.5	[18.8-56.7]	59	79.2	[65.8-88.3]
VPO_3	DRC - Boko	249	53.9	[46.1-61.5]	89	27.4	[17.4-40.2]	94	55.6	[31.7-77.1]	52	49,0	[26.1-72.4]
	DRC - Ndjili	255	84.7	[79.6-88.8]	90	90.2	[77.6-96.1]	84	95.7	[85.8-98.8]	58	93.7	[84.0-97.7]
	CAR - Bangui II	245	68.1	[62.2-73.5]	106	74.3	[65.6-81.3]	81	72.7	[55.4-85.1]	55	75.3	[58.8-86.7]
	CAR - Begoua	272	59.3	[52.7-65.6]	91	79.9	[61.4-90.8]	94	53.7	[44.1-63.0]	61	55.2	[40.6-68.9]
	CAR - Bossembele	261	32.2	[25.4-39.9]	90	18.1	[11.9-26.6]	65	27.5	[13.6-47.9]	59	56.7	[39.5-72.5]

Vaccination coverage of children aged 12-23 months by two combined sources for all antigens in the pilot study by HZ/HD and method in DRC and CAR, 2023

Antigen	Health zone/Health district	WHO			WHO-KSPH			GIS			LQAS		
		n	%	CI 95%	n	%	CI 95%	n	%	CI 95%	n	%	CI 95%
Penta 1	DRC - Boko	249	74.6	[67.3-80.6]	89	47,0	[32.3-62.1]	94	71.6	[45.8-88.3]	52	60.0	[36.4-79.7]
	DRC - Ndjili	255	80.2	[74.2-85.0]	90	91.9	[81.5-96.7]	84	100.0		58	95.1	[83.4-98.7]
	CAR - Bangui II	245	78.3	[71.4-83.9]	106	90,0	[78.4-95.8]	81	90.0	[86.5-92.7]	55	81.6	[70.4-89.2]
	CAR - Begoua	272	76.4	[69.3-82.3]	91	90.3	[76.1-96.5]	94	75.0	[66.6-81.8]	61	66.5	[52.1-78.3]
	CAR - Bossembele	261	48.8	[40.7-57.1]	90	44.5	[28.6-61.7]	65	36.9	[22.7-53.8]	59	80.0	[59.8-91.5]
Penta 2	DRC - Boko	249	65.1	[57.7-71.9]	89	30.5	[19.6-44.1]	94	67.6	[43.3-85.1]	52	53.1	[31.4-73.7]
	DRC - Ndjili	255	78.1	[71.7-83.4]	90	90.2	[77.6-96.1]	84	100.0		58	93.7	[84.0-97.7]
	CAR - Bangui II	245	73.7	[67.1-79.3]	106	83.5	[72.2-90.8]	81	84.6	[74.8-91.0]	55	80.7	[70.4-88.1]
	CAR - Begoua	272	70.5	[62.7-77.2]	91	83.5	[66.2-92.9]	94	67.9	[59.3-75.5]	61	55.3	[40.1-69.6]
	CAR - Bossembele	261	40.4	[32.9-48.3]	90	23.4	[16.3-32.2]	65	31,0	[15.4-52.5]	59	71.6	[52.9-85.0]
Penta 3	DRC - Boko	249	50.2	[42.7-57.8]	89	25.0	[15.8-37.2]	94	54.1	[32.9-74.0]	52	47.3	[26.2-69.5]
	DRC - Ndjili	255	71.0	[64.2-77.0]	90	90.2	[77.6-96.1]	84	94.7	[86.6-98.1]	58	90.5	[82.1-95.2]
	CAR - Bangui II	245	66.9	[60.5-72.7]	106	75.3	[66.4-82.5]	81	72.8	[54.6-85.6]	55	75.3	[60.6-85.8]
	CAR - Begoua	272	58.7	[51.2-65.9]	91	77.6	[61.0-88.4]	94	53.8	[43.1-64.1]	61	48.8	[37.1-60.7]
	CAR - Bossembele	261	31.5	[24.7-39.1]	90	15.3	[9.4-23.9]	65	24.7	[9.6-50.3]	59	52.4	[35.6-68.6]
PCV 1	DRC - Boko	249	74.4	[67.2-80.5]	89	45.7	[31.3-61.0]	94	71.6	[45.8-88.3]	52	56.3	[34.7-75.7]
	DRC - Ndjili	255	79.7	[73.6-84.7]	90	91.9	[81.5-96.7]	84	100.0		58	93.7	[84.0-97.7]
	CAR - Bangui II	245	74.5	[67.8-80.2]	106	88.2	[75.4-94.8]	81	87.3	[80.5-91.9]	55	81.6	[70.4-89.2]
	CAR - Begoua	272	77.4	[71.1-82.7]	91	90.3	[76.1-96.5]	94	71.8	[63.4-79.0]	61	63.1	[47.8-76.2]
	CAR - Bossembele	261	48.5	[40.3-56.9]	90	43.9	[29.5-59.5]	65	36.9	[22.7-53.8]	59	77.9	[60.1-89.2]
PCV 2	DRC - Boko	249	62.9	[55.1-70.1]	89	28.4	[17.5-42.5]	94	67.5	[43.6-84.7]	52	51,0	[30.4-71.2]
	DRC - Ndjili	255	77.7	[71.2-83.0]	90	89.2	[75.5-95.7]	84	100,0		58	92.3	[81.9-96.9]
	CAR - Bangui II	245	70.5	[63.9-76.3]	106	78.2	[67.9-85.9]	81	79.1	[68.4-86.9]	55	80.7	[70.4-88.1]
	CAR - Begoua	272	70.7	[63.6-76.9]	91	83.5	[66.2-92.9]	94	64.8	[54.3-74.1]	61	47.7	[31.6-64.3]
	CAR - Bossembele	261	39,0	[31.6-47.0]	90	24,0	[17.1-32.6]	65	26.4	[11.3-50.2]	59	67.3	[53.3-78.7]
PCV 3	DRC - Boko	249	49.1	[41.4-56.7]	89	25.2	[14.4-40.2]	94	51.6	[27.9-74.5]	52	45.2	[25.5-66.5]
	DRC - Ndjili	255	69.7	[62.9-75.8]	90	89.2	[75.5-95.7]	84	96.4	[91.7-98.5]	58	92.3	[81.9-96.9]
	CAR - Bangui II	245	62.6	[55.7-69.1]	106	73.5	[64.2-81.1]	81	70.4	[54.2-82.7]	55	75.3	[60.6-85.8]
	CAR - Begoua	272	57.3	[50.1-64.2]	91	75.8	[60.7-86.4]	94	52.7	[42.3-62.8]	61	40.4	[29.3-52.6]
	CAR - Bossembele	261	30.6	[23.9-38.3]	90	14.0	[7.4-24.9]	65	22.9	[9.6-45.4]	59	52.4	[35.6-68.6]

Vaccination coverage of children aged 12-23 months by two combined sources for all antigens in the pilot study by HZ/HD and method in DRC and CAR, 2023

Antigen	Health zone/Health district	WHO			WHO-KSPH			GIS			LQAS		
		n	%	CI 95%	n	%	CI 95%	n	%	CI 95%	n	%	CI 95%
ROTA 1	DRC - Boko	249	69.9	[62.5-76.4]	89	38.4	[24.6-54.3]	94	69.1	[40.3-88.0]	52	52.2	[28.7-74.8]
	DRC - Ndjili	255	79.4	[73.2-84.4]	90	88.4	[73.6-95.4]	84	98.4	[90.3-99.8]	58	93.7	[83.9-97.7]
ROTA 2	DRC - Boko	249	57.1	[49.4-64.6]	89	28.0	[16.8-43.0]	94	63.2	[35.4-84.3]	52	45.5	[24.4-68.3]
	DRC - Ndjili	255	72.7	[66.1-78.4]	90	85.9	[67.8-94.6]	84	95.3	[75.3-99.3]	58	93.7	[83.9-97.7]
ROTA 3	DRC - Boko	249	47.2	[39.4-55.1]	89	13.7	[7.8-23.1]	94	48.3	[23.2-74.3]	52	31.4	[18.2-48.6]
	DRC - Ndjili	255	69.3	[62.5-75.4]	90	83.1	[64.1-93.1]	84	92.5	[72.3-98.3]	58	92.3	[81.8-96.9]
VPI	DRC - Boko	249	51.3	[43.5-58.9]	89	27.0	[15.7-42.2]	94	48.8	[26.9-71.1]	52	49.0	[26.1-72.4]
	DRC - Ndjili	255	71.7	[64.7-77.8]	90	69,0	[45.9-85.4]	84	88.7	[67.9-96.7]	58	58.5	[47.7-68.6]
	CAR - Bangui II	245	63.3	[57.5-68.7]	106	68.1	[54.0-79.6]	81	68.5	[58.5-77.0]	55	61.8	[46.5-75.1]
	CAR - Begoua	272	55.4	[47.6-63.0]	91	83.2	[65.7-92.8]	94	36.1	[27.3-46.0]	61	38.7	[24.8-54.7]
	CAR - Bossembele	261	32.9	[26.3-40.3]	90	19,0	[9.8-33.6]	65	20.1	[5.2-53.7]	59	42.4	[28.0-58.2]
VAA	DRC - Boko	249	47.4	[40.1-54.9]	89	24,0	[14.9-36.4]	94	42.9	[22.9-65.5]	52	41.9	[25.1-60.9]
	DRC - Ndjili	255	86.6	[81.4-90.5]	90	85.7	[74.7-92.4]	84	84.0	[70.8-91.9]	58	84.6	[78.2-89.4]
	CAR - Bangui II	245	56,0	[49.7-62.1]	106	54.5	[46.8-62.0]	81	68.6	[56.1-78.9]	55	62.4	[48.1-74.8]
	CAR - Begoua	272	44.1	[37.0-51.3]	91	61.4	[51.3-70.7]	94	29.3	[17.3-45.0]	61	32.6	[24.3-42.2]
	CAR - Bossembele	261	18.1	[12.6-25.3]	90	13.0	[6.5-24.5]	65	20.6	[10.4-36.6]	59	42.7	[23.9-64.0]
VAR	DRC - Boko	249	49.5	[42.0-56.9]	89	24.9	[16.1-36.4]	94	44.6	[26.0-64.9]	52	44.1	[26.9-62.8]
	DRC - Ndjili	255	87.4	[82.3-91.1]	90	85.7	[74.7-92.4]	84	87.2	[79.7-92.2]	58	86.1	[78.4-91.3]
	CAR - Bangui II	245	54.8	[48.6-60.9]	106	55.4	[47.2-63.3]	81	68.6	[56.1-78.9]	55	61.2	[48.4-72.6]
	CAR - Begoua	272	44.1	[37.0-51.3]	91	61.4	[51.3-70.7]	94	29.3	[17.3-45.0]	61	31.8	[23.1-42.0]
	CAR - Bossembele	261	18.2	[12.5-25.8]	90	11.4	[6.1-20.4]	65	21.6	[15.6-29.0]	59	45.3	[27.5-64.4]
MEN	CAR - Bangui II	245	50.6	[44.1-57.0]	106	55.4	[47.1-63.3]	81	63.7	[51.5-74.4]	55	55.2	[38.1-71.1]
	CAR - Begoua	272	42.6	[35.8-49.8]	91	61.4	[51.2-70.7]	94	30.2	[18.0-46.1]	61	27.4	[19.8-36.6]
	CAR - Bossembele	261	17.1	[11.6-24.4]	90	13.7	[6.9-25.4]	65	21.1	[9.5-40.5]	59	42.7	[23.8-64.0]
Zero Dose	DRC - Boko	249	25.4	[19.4-32.7]	89	53.0	[37.9-67.7]	94	28.4	[11.7-54.2]	52	40.0	[20.3-63.6]
	DRC - Ndjili	255	19.8	[15.0-25.8]	90	8.1	[3.3-18.5]	84	0,0		58	4.9	[1.3-16.6]
	CAR - Bangui II	245	21.7	[16.1-28.6]	106	10,0	[4.2-21.6]	81	10,0	[7.3-13.5]	55	18.4	[10.8-29.6]
	CAR - Begoua	272	23.6	[17.7-30.7]	91	9.7	[3.5-23.9]	94	25,0	[18.2-33.4]	61	33.5	[21.7-47.9]
	CAR - Bossembele	261	51.2	[42.9-59.3]	90	55.5	[38.3-71.4]	65	63.1	[46.2-77.3]	59	20.0	[8.5-40.2]

14. Annex 1. Cost Estimation Analysis Report

Comparative Pilot Study of Methods for Assessing Routine Vaccine Coverage in Health Districts of the DRC and CAR: Cost and Cost Effectiveness Analysis Protocol

Background

While standard matrices of vaccine coverage surveys are typically vaccine coverage estimates and estimates of zero dose children, there are a number of elements which should be taken into account when selecting a study methodology. These elements include factors related to accuracy and precision, time and cost. This study tests multiple vaccine coverage survey methodologies in different settings – the Democratic Republic of the Congo (DRC) and the Central African Republic (RCA) in both urban and rural health zones/districts. While a primary factor is having accurate estimates – cost and cost analysis of the survey methods used in this study may help guide future researchers to determine not only which methodologies may be used for a large-scale survey in their country context but also which survey technique will represent better value for money in their context.

Surveys used for monitoring purposes have been implemented nationwide in DRC since 2021. The methodology used by the DRC is a modified version of the suggested WHO Rapid Coverage Survey Methodology, which collects data from five clusters from each health zone, which can then be aggregated to provide provincial estimates approved for inclusion in the WUENIC yearly estimates. In the DRC, there are no provinces with less than 10 health zones – thus ensuring that at the provincial level, estimates are considered accurate, while having representation from every health zone to provide some operational feedback. Following the success of the DRC in implementing yearly surveys, other LMIC/high priority countries for improving routine immunization have started discussions on how to implement similar vaccine coverage monitoring tools.

Methods

This study estimates cost and cost-effectiveness of five different survey methodologies implemented in DR Congo and CAR. Financial, economic and fiscal costs are analyzed. Costs cover coordination costs as well as survey implementation costs. Coordination costs include protocol development for all survey methods, site selection, GIS site selection and map development, and study implementation preparation by a central team. Survey implementation costs include personnel time, per diems, transportation, training, communications, supplies, and small equipment.

The approaches for evaluating each of those cost inputs are described below.

For categories in which the costs were shared (coordination & training) across methods, it can be divided by four methods. [Coordination time would be similar over the methods; divided by the number of people and multiplied by the number of people in each method].

Fiscal costs represent the actual expenditures made for each of the survey methods. This information is disaggregated by different line items. Fiscal costs are also broken down by household, cluster and health zone. For this study, the WHO-KSPH and GIS method had 5 additional clusters (10 clusters total) collected for each method – thus costs will be divided to account for the standard 5 cluster method when looking at the health zone costs. The cost per cluster and household could be used to help optimize costs for future studies[3].

Time measurements: time measurements were not taken at the point when an interviewer left their house, but instead from where they departed to go to the cluster. For urban health zones/districts, this time would be similar to when they left their house and returned at the end of each day. For rural health zones, the time to get to each location was identified and added into the number of days spent undertaking the field work. [Training cost per person was the same. Only scaled up by the number of participants].

We set the number of days for each method. While some teams may have finished earlier than planned (for example some teams finished with 1 remaining day scheduled for work), all members were paid in full based on the number of estimated days of work. No teams went over the expected time. We also assumed an average time per cluster. However, we have noted some discrepancies in between planned and actual time in each cluster, which may be related to issues with tablets and surveys for time collection – especially if an interviewer did not save after completing or if they went backwards in the survey, that might trigger updating times. This will help facilitate calculations for average time per cluster and between clusters. For the WHO-KSPH and GIS method, this will need to be adjusted for the 5 vs 10 clusters.

Study team members can contribute information on how much time certain elements can take to determine if they are evenly distributed between methods or if there are differences in time for one method vs another.

1. Staff time

a. Person time – supervisors, per diem + salary: The salary costs were the same over all methods. However, depending on if teams were required to stay overnight in a location or not - their daily per diem rate was varied. For example, in urban areas, where the teams returned home each night, they typically received $10 per diem per day whereas teams that to stay outside of the house typically received $30 per diem per day. This was the same for the interviewers.

HZ/District	Method	# Supervisors	Daily per diem	Daily honoraire	Number of days	Cost	Cost Per Cluster
Ndjili	WHO	1	$10.00	$50.00	14	**$840.00**	$20.49
	KSPH	2	$10.00	$50.00	10	**$1,200.00**	$120.00

[3] standard methods = 5 clusters; added in 5 more clusters. Not standard practice. So, the actual process was inflated, doubling the cost of field work. 2 teams that each did 5 clusters. In previous analysis - made it as a sensitivity analysis. But now use it as well. Cost/cluster would be a comparator.

	GIS	2	$10.00	$50.00	10	**$1,200.00**	$120.00
	LQAS	1	$10.00	$50.00	10	**$600.00**	$120.00
Boko	WHO	1	$30.00	$50.00	17	**$1,360.00**	$33.17
	KSPH	2	$30.00	$50.00	13	**$2,080.00**	$208.00
	GIS	2	$30.00	$50.00	13	**$2,080.00**	$208.00
	LQAS	1	$30.00	$50.00	13	**$1,040.00**	$208.00
Bangui II	WHO	1	$10.00	$50.00	14	**$840.00**	$20.49
	KSPH	2	$10.00	$50.00	10	**$1,200.00**	$120.00
	GIS	2	$10.00	$50.00	10	**$1,200.00**	$120.00
	LQAS	1	$10.00	$50.00	10	**$600.00**	$120.00
Begoua	WHO	1	$30.00	$50.00	16	**$1,280.00**	$31.22
	KSPH	1	$30.00	$50.00	12	**$960.00**	$192.00
	GIS	1	$30.00	$50.00	12	**$960.00**	$192.00
	LQAS	1	$30.00	$50.00	12	**$960.00**	$192.00
Bossembele	WHO	1	$30.00	$50.00	16	**$1,280.00**	$31.22
	KSPH	2	$30.00	$50.00	12	**$1,920.00**	$192.00
	GIS	2	$30.00	$50.00	12	**$1,920.00**	$192.00
	LQAS	1	$30.00	$50.00	12	**$960.00**	$192.00

b. Person time – interviewers, per diem + salary

HZ/District	Method	# Interviewers	Daily per diem	Daily honoraire	Number of days	Cost	Cost Per Cluster
Ndjili	WHO	6	$10.00	$30.00	14	**$3,360.00**	$81.95
	KSPH	8	$10.00	$30.00	10	**$3,200.00**	$320.00
	GIS	8	$10.00	$30.00	10	**$3,200.00**	$320.00
	LQAS	2	$10.00	$30.00	10	**$800.00**	$160.00
Boko	WHO	6	$30.00	$30.00	17	**$6,120.00**	$149.27
	KSPH	8	$30.00	$30.00	13	**$6,240.00**	$624.00
	GIS	8	$30.00	$30.00	13	**$6,240.00**	$624.00
	LQAS	2	$30.00	$30.00	13	**$1,560.00**	$312.00
Bangui II	WHO	6	$10.00	$30.00	14	**$3,360.00**	$81.95

	KSPH	8	$10.00	$30.00	10	**$3,200.00**	$320.00
	GIS	8	$10.00	$30.00	10	**$3,200.00**	$320.00
	LQAS	2	$10.00	$30.00	10	**$800.00**	$160.00
Begoua	WHO	6	$30.00	$30.00	16	**$5,760.00**	$140.49
	KSPH	4	$30.00	$30.00	12	**$2,880.00**	$576.00
	GIS	4	$30.00	$30.00	12	**$2,880.00**	$576.00
	LQAS	2	$30.00	$30.00	12	**$1,440.00**	$288.00
Bossembele	WHO	6	$30.00	$30.00	16	**$5,760.00**	$140.49
	KSPH	8	$30.00	$30.00	12	**$5,760.00**	$576.00
	GIS	8	$30.00	$30.00	12	**$5,760.00**	$576.00
	LQAS	2	$30.00	$30.00	12	**$1,440.00**	$288.00

c. Guides (same for all clusters)- paid on a per cluster basis and they were provided a lump sum for all of the clusters. The guides were hired as a local aid, in order to help the teams navigate the cluster and meet with local leaders.

HZ/District	Method	# Clusters completed/# planned	Amount per cluster	Cost (all clusters)	Cost (method correct # of clusters)
Ndjili	WHO	41	$5.00	**$205.00**	$205.00
	KSPH	10/5	$5.00	**$50.00**	$25.00
	GIS	10/5	$5.00	**$50.00**	$25.00
	LQAS	5	$5.00	**$25.00**	$125.00
Boko	WHO	41	$10.00	**$410.00**	$410.00
	KSPH	10/5	$10.00	**$100.00**	$50.00
	GIS	10/5	$10.00	**$100.00**	$50.00
	LQAS	5	$10.00	**$50.00**	$250.00
Bangui II	WHO	41	$5.00	**$205.00**	$205.00
	KSPH	10/5	$5.00	**$50.00**	$25.00
	GIS	10/5	$5.00	**$50.00**	$25.00
	LQAS	5	$5.00	**$25.00**	$125.00
Begoua	WHO	41	$10.00	**$410.00**	$410.00
	KSPH	5	$10.00	**$50.00**	$50.00
	GIS	5	$10.00	**$50.00**	$50.00

	LQAS	5	$10.00	**$50.00**	$250.00
Bossembele	WHO	41	$10.00	**$410.00**	$410.00
	KSPH	10/5	$10.00	**$100.00**	$50.00
	GIS	10/5	$10.00	**$100.00**	$50.00
	LQAS	5	$10.00	**$50.00**	$250.00

d. Transportation: The transportation cost varied if urban vs. rural - as the rural clusters required additional transportation to the HZ/HD and also to get to each cluster. This should be accounted for when planning a VCS - what proportion of HZ/HD are urban vs. rural. In the DRC, the team members were given transport stipend individually to get to their HZ. In CAR, the coordination team arranged group transport. This table presents the base cost (as paid out based on the contracts, see detailed CEA summary sheet to see adjusted costs).

HZ/District	Method	# Interviewers	# Supervisors	# Teams	Combined cost for transport to/from site	Daily cost per interviewer	Daily cost per supervisor	Number of days	Cost
Ndjili	WHO	6	1	1		$10.00	$15.00	14	**$1,050.00**
	KSPH	8	2	2		$10.00	$15.00	10	**$1,100.00**
	GIS	8	2	2		$10.00	$15.00	10	**$1,100.00**
	LQAS	2	1	1		$10.00	$15.00	10	**$350.00**
Boko	WHO	6	1	1	$525.00	$25.00	$35.00	14	**$2,590.00**
	KSPH	8	2	2	$795.00	$25.00	$35.00	10	**$2,700.00**
	GIS	8	2	2	$750.00	$25.00	$35.00	10	**$2,700.00**
	LQAS	2	1	1	$225.00	$25.00	$35.00	10	**$850.00**
Bangui II	WHO	6	1	1		$10.00	$15.00	14	**$1,050.00**
	KSPH	8	2	2		$10.00	$15.00	10	**$1,100.00**
	GIS	8	2	2		$10.00	$15.00	10	**$1,100.00**
	LQAS	2	1	1		$10.00	$15.00	10	**$350.00**
Begoua	WHO	6	1	1	$649.00	$25.00	$35.00	14	**$2,590.00**

	KSPH	4	1	1	$214.00	$25.00	$35.00	10	**$1,350.00**
	GIS	4	1	1	$439.00	$25.00	$35.00	10	**$1,350.00**
	LQAS	2	1	1	$417.00	$25.00	$35.00	10	**$850.00**
Bossembele	WHO	6	1	1	$874.00	$25.00	$35.00	14	**$2,590.00**
	KSPH	8	2	2	$821.00	$25.00	$35.00	10	**$2,700.00**
	GIS	8	2	2	$345.00	$25.00	$35.00	10	**$2,700.00**
	LQAS	2	1	1	$479.00	$25.00	$35.00	10	**$850.00**

e. Communication: each interviewer received $20 for the period of the survey; each supervisor received $100 for the period of the survey. This has been a standard amount given during previous DRC VCS.

HZ/District	Method	# Interviewers	# Supervisors	Cost per supervisor	Cost per interviewer	Total Cost
Ndjili	WHO	6	1	$100.00	$20.00	$220.00
	KSPH	8	2	$100.00	$20.00	$360.00
	GIS	8	2	$100.00	$20.00	$360.00
	LQAS	2	1	$100.00	$20.00	$140.00
Boko	WHO	6	1	$100.00	$20.00	$220.00
	KSPH	8	2	$100.00	$20.00	$360.00
	GIS	8	2	$100.00	$20.00	$360.00
	LQAS	2	1	$100.00	$20.00	$140.00
Bangui II	WHO	6	1	$100.00	$20.00	$220.00
	KSPH	8	2	$100.00	$20.00	$360.00
	GIS	8	2	$100.00	$20.00	$360.00
	LQAS	2	1	$100.00	$20.00	$140.00
Begoua	WHO	6	1	$100.00	$20.00	$220.00
	KSPH	4	2	$100.00	$20.00	$280.00
	GIS	4	2	$100.00	$20.00	$280.00
	LQAS	2	1	$100.00	$20.00	$140.00

Bossembele	WHO	6	1	$100.00	$20.00	$220.00
	KSPH	8	2	$100.00	$20.00	$360.00
	GIS	8	2	$100.00	$20.00	$360.00
	LQAS	2	1	$100.00	$20.00	$140.00

2. Materials and Equipment

a. Reusable materials: These are materials that were purchased for either a team or by method. In the DRC, there were already tablets that could be used for this survey. Thus, we used an annualized cost for each tablet - taking the purchase price divided over 5 years of use, and then used for 1 month of the year. In CAR, there were no tablets available, thus these were purchased for this study. Aromatizing the tablet cost if tablets are used in the future, will reduce the cost estimates.

Reusable Materials	**DRC**					**CAR**				
	Cost/ item	WHO (14)	KSPH (20)	GIS (20)	LQAS (6)	Cost/ unit	WHO (21)	KSPH (25)	GIS (25)	LQAS (9)
Tablet and charger (Samsung Tab A7)	$5.00	$70.00	$100.00	$100.00	$30.00	$250.00	$5,250.00	$6,250.00	$6,250.00	$2,250.00
Battery Pack	$2.00	--	--	$40.00	--	$42.00	--	--	$1,050.00	--
Power strip	$15.00	$30.00	$45.00	$45.00	$15.00	$7.50	$15.00	$22.50	$22.50	$7.50
Suitcase	--	--	--	--	--	$60.00	$15.00	$15.00	$15.00	$15.00
Staplers	$9.00	$9.00	$9.00	$9.00	$9.00	$9.00	$9.00	$9.00	$9.00	$9.00
Total		$109.00	$154.00	$194.00	$54.00		$5,289.00	$6,296.50	$7,346.50	$2,281.50
*For DRC, the tablet, charger and battery pack are amortized costs - as these were available and in-kind donations for use on this project.										

b. Consumables: These kits were purchased in advance by the coordination administration and were distributed to each interviewer and supervisor before deployment. For the purpose of this analysis, we used the conversion rate: CAR: 1USD = 600XAF. In DRC all costs were paid in USD.

Consumables (by method)	**DRC**					**CAR**				
	Cost/person	WHO (14)	KSPH (20)	GIS (20)	LQAS (6)	Cost/person	WHO (21)	KSPH (25)	GIS (25)	LQAS (9)

Backpack	$25.00	$350.00	$500.00	$500.00	$150.00	$17.00	$357.00	$425.00	$425.00	$153.00
Pens	$2.00	$28.00	$40.00	$40.00	$12.00	$2.00	$42.00	$50.00	$50.00	$18.00
Antibacterial gel	$1.00	$14.00	$20.00	$20.00	$6.00	$1.00	$21.00	$25.00	$25.00	$9.00
Rain jackets*	$20.00	$140.00	$200.00	$200.00	$60.00	$17.00	$357.00	$425.00	$425.00	$153.00
Docs Interviewer	$0.50	$7.00	$10.00	$10.00	$3.00	$0.50	$10.50	$12.50	$12.50	$4.50
Docs supervisor	$2.00	$28.00	$40.00	$40.00	$12.00	$2.00	$42.00	$50.00	$50.00	$18.00
Safety vests	--					$42.00	$882.00	$1,050.00	$1,050.00	$378.00
Notebook	$1.00	$14.00	$20.00	$20.00	$6.00	$1.00	$21.00	$25.00	$25.00	$9.00
Makers	$1.00	$14.00	$20.00	$20.00	$6.00	$1.00	$21.00	$25.00	$25.00	$9.00
Aggrafe (paquet)	$2.00	$28.00	$40.00	$40.00	$12.00	$2.00	$42.00	$50.00	$50.00	$18.00
Total	$54.50	$623.00	$890.00	$890.00	$267.00	$85.50	$1,795.50	$2,137.50	$2,137.50	$769.50

*Only purchased for N'Djili teams for DRC. All members for CAR received a rain jacket

c. Field consumable costs: These were costs paid by the administration team and exact figures are based on standard costs derived from previous studies. For fuel in CAR, this amount was given to teams based on an estimation of how much fuel they would require to charge tablets for the duration of the study. These costs are estimated by team, not individual.

Field Consumables (by Team)	**DRC**					**CAR**				
	Cost/ unit	WHO (14)	KSPH (20)	GIS (20)	LQAS (6)	Cost/ unit	WHO (21)	KSPH (25)	GIS (25)	LQAS (9)
Barcodes	$2.00	$82.00	$20.00	$20.00	$10.00	$2.00	$82.00	$20.00	$20.00	$10.00
Maps	$10.00	$20.00	$40.00	$40.00	$20.00	$10.00	$30.00	$50.00	$50.00	$30.00
Pack of paper	$6.00	$6.00	$6.00	$6.00	$6.00	$8.50	$8.50	$8.50	$8.50	$8.50
Ink cartridges	$90.00	$90.00	$90.00	$90.00	$90.00	$267.00	$267.00	$267.00	$267.00	$267.00
Carburant groupe électrogène (per L)*	--					$2.50	$100.00	$90.00	$90.00	$90.00
MUAC - arm band	$1.00	$14.00	$20.00	$20.00	$6.00	$1.00	$21.00	$25.00	$25.00	$25.00
Total		$212.00	$176.00	$176.00	$132.00		$508.50	$460.50	$460.50	$430.50

*Fuel only given to teams in Bossembele

d. Overall Equipment and Material costs

	DRC				CAR			
Consumables and Equipment	WHO	KSPH	GIS	LQAS	WHO	KSPH	GIS	LQAS
a. Reusable materials	$109.00	$154.00	$194.00	$54.00	$5,289.00	$6,296.50	$7,346.50	$2,281.50
b. Individual consumables	$623.00	$890.00	$890.00	$267.00	$1,795.50	$2,137.50	$2,137.50	$769.50
c. Team consumables	$212.00	$176.00	$176.00	$132.00	$508.50	$460.50	$460.50	$430.50
Total	**$944.00**	**$1,220.00**	**$1,260.00**	**$453.00**	**$7,593.00**	**$8,894.50**	**$9,944.50**	**$3,481.50**
Total per person	$67.43	$61.00	$63.00	$22.65	$361.57	$355.78	$397.78	$386.83

3. Training:

Training was provided over 6 days. All team members had the same general training for 3.5 days. There was a 4-hour block devoted to specific training for each method where participants were split into their respective methodology teams. Teams were also split during the one-day pre-test. Training costs included transport reimbursement (for participants paid directly); room rental; catering/food costs; pre-testing transportation; and, consumables (allocated to each participant). The total cost for training was divided by the number of total participants, and then multiplied by the number of people in each team for each method. The same training protocol was implemented in both countries. During the training, three additional people per method were selected as "back-ups" in case there was someone who dropped out or was unable to do the field work. These 3 people are added for training only.

DRC Training actual costs							
Item	**Total cost**	**Cost / person (4 days)**	**Coordination (13)**	**WHO DRC (14)**	KSPH**DRC (20)**	**GIS DRC (20)**	**LQAS DRC (6)**
Room for training	$0.00						
Food (in class)	$6,935.00	$95.00	$1,235.00	$1,330.00	$1,900.00	$1,900.00	$570.00
Transport (training)	$2,400.00	$40.00		$560.00	$800.00	$800.00	$240.00
Car rental (pre-test)	$0.00						
Fuel (pre-test)	$0.00						
Consumables	$500.00	$6.85	$89.04	$95.89	$136.99	$136.99	$41.10
TOTAL	$9,835.00		$1,324.04	$1,985.89	$2,836.99	$2,836.99	$851.10
Cost per person trained							

3 additional people for back-ups so that people can be substituted as needed.
The room for training, car rental, and fuel were in-kind donations from KSPH. No funds were spent on these items in DRC

DRC Training estimated costs							
Item	**Total cost**	**Cost / person (4 days)**	**Coordination (13)**	**WHO DRC (14)**	KSPH**DRC (20)**	**GIS DRC (20)**	**LQAS DRC (6)**
Room for training *Estimated	$2,400.00	$32.88	$427.40	$460.27	$657.53	$657.53	$197.26
Food (in class)	$6,935.00	$95.00	$1,235.00	$1,330.00	$1,900.00	$1,900.00	$570.00
Transport (training)	$2,920.00	$40.00	$520.00	$560.00	$800.00	$800.00	$240.00
Car rental (pre-test) *Estimated	$500.00		$100.00	$100.00	$100.00	$100.00	$100.00
Fuel (pre-test) *Estimated	$500.00		$100.00	$100.00	$100.00	$100.00	$100.00
Consumables	$650.00	$8.90	$115.75	$124.66	$178.08	$178.08	$53.42
TOTAL	$13,905.00		$2,498.15	$2,674.93	$3,735.62	$3,735.62	$1,260.68
Cost per person trained			$192.17	$191.07	$186.78	$186.78	$210.11
This is if all in-kind items had been paid. There was a savings of $3,550							

4. Coordination costs

Total costs (end to end): Coordination costs were incurred across all four methodologies. While there may be some specific costs associated with each method, such as the procedures for weighting samples.

a. Coordination costs – protocol development, ethics approvals, data management, data analysis. This also includes personnel time. Overall, the UCLA team provided support to both the DRC and CAR team, the KSPH also provided support to both teams, while the CAR team primarily supported the CAR survey. Thus, the CAR survey costs were higher than the DRC survey costs for all methods.

b. Dissemination meetings in each country: In the DRC, the bi-annual annual EPI meeting held outside of Kinshasa was used as a forum for result dissemination in DRC. In CAR, there was a specific event held for the dissemination of the results presided by the Minister of Health. This meeting includes transportations, subsistence allowance, and support from two DRC colleagues.

c. Indirect/Overhead Costs: These are administrative costs that are factored into the budget for overhead that each institution charges. The BMGF sets the overhead cost to a maximum of 10%. Thus, in DRC, the overhead cost was 10% and as the funds were sent from DRC, there was 10% and an additional 3% to cover bank fees in CAR. Each country may have a different overhead cost - up to 10% if funded through BMGF.

	DRC Survey	CAR Survey
Meetings (planned)	$500.00	$5,000.00
Communication/Internet	$400.00	$3,000.00
Training (taken from training tabs)	$1,324.04	$3,646.43
Staff time DRC	$20,000.00	$48,000.00
Staff time CAR		$84,000.00
Staff time USA	$15,000.00	$25,000.00
Travel to DRC during training	$18,000.00	
Travel to CAR during training		$21,000.00
Travel to CAR during dissemination		$17,000.00
Staff time for Analysis	$20,000.00	$24,000.00
Dissemination	$3,500.00	$5,000.00
Total	$78,724.04	$235,646.43

Sensitivity analysis

We conducted a basic sensitivity analysis to explore how certain variations would affect cost of survey implementation.

1. Calculated person time: To reduce the effect of constraints imposed by the coordination team, sensitivity analysis was carried out to generate the actual workloads for data collection so as to achieve the same numbers of eligible households as obtained by each method in this study (Table 12). The team used a team of five people as its implementation unit, including four investigators and a supervisor. Each team member was instructed to collect data from 6 households each day, totaling 30 households per team per day.

Estimated workload in person-days to achieve results by method and site using estimates provided to interviewers to complete 6 questionnaires per day.

Health zone/Health District	WHO	KSPH	GIS	LQAS
DRC N'djili	13.60	4.97	5.07	2.90
DRC Boko	13.93	4.97	5.23	3.13
CAR Bangui II	13.20	5.17	5.03	3.17
CAR Bégoua	13.63	4.47	5.00	3.20
CAR Bossembele	12.70	5.67	3.77	3.17

Thus, to carry out data collection using the WHO method as implemented in the Ndjili HZ and obtain 418 eligible households using the team of five people, 13.60 person-days are required. In HD Bossembele, 12.7 person-days are required to implement the study with a team of five people. However, to achieving the results as obtained in the Ndjili HZ using the LQAS method with a team of five people required 2.9 person-days. These workloads do not take into account travel distances, and thus could be underestimated for long distances. These word day estiamtes could then be used to generate cost per method (adjusted for this sensitivity analysis).

Data collection costs based on workloads by method and site (Scenario 1)

HD/HZ	WHO	KSPH	GIS	LQAS
DRC Ndjili	34,305.29	14,576.93	14,598.93	5,944.20
DRC Boko	39,205.79	19,801.93	19,348.93	7,566.70
CAR Bangui II	69,916.00	27,397.09	27,884.29	11,610.80
CAR Begoua	75,721.57	16,569.55	16,813.15	13,321.80
CAR Bossembele	75,721.57	32,907.09	33,394.29	13,321.80

These costs can then be looked at as ratios to the gold standard – to see the variation in the method.

Cost ratios based on actual expenditure by method and site (Scenario 1)

HZ/HD	WHO	KSPH	GIS	LQAS
DRC Ndjili	1.00	0.42	0.43	0.17
DRC Boko	1.00	0.51	0.49	0.19
CAR Bangui II	1.00	0.39	0.40	0.17
CAR Begoua	1.00	0.22	0.22	0.18
CAR Bossembele	1.00	0.43	0.44	0.18

For example, when taking the adjusted sensitivity costs for interviewer/supervisor time into account, LQAS expenditure in the N'djili ZS was 17% that of the WHO method. On the other hand, GIS and KSPH costs were about the same and were about 40% of those of the WHO method.

<u>2. Actual person time costs – based on tracking survey completion and supervision data:</u> During the course of the survey, all interviewers were asked to report times they left their house, administrative meetings, enumeration or cluster location times, and actual times for completing surveys (these times were automatically stored in the questionnaire). This data provided general

estimates for each HZ/HD and method on time to completion. Variation is expected between each individual, and thus may not provide a fully accurate timing on total time to complete the study. In general, there was between a 15% to 25% reduction in time needed compared to what was paid for each persons contract. This could help future coordination teams on exploring cost effective solutions to ensure time is accurately estimated.

Supervision time:

HZ/District	Method	# Supervisors	Daily per diem	Daily honoraire	No of days	Cost	Cost Per Cluster	% Reduction
Ndjili	WHO	1	$10.00	$50.00	12	**$720.00**	$17.56	14.3%
	KSPH	2	$10.00	$50.00	8	**$960.00**	$96.00	20.0%
	GIS	2	$10.00	$50.00	8	**$960.00**	$96.00	20.0%
	LQAS	1	$10.00	$50.00	8	**$480.00**	$96.00	20.0%
Boko	WHO	1	$30.00	$50.00	14	**$1,120.00**	$27.32	17.6%
	KSPH	2	$30.00	$50.00	10	**$1,600.00**	$160.00	23.1%
	GIS	2	$30.00	$50.00	10	**$1,600.00**	$160.00	23.1%
	LQAS	1	$30.00	$50.00	10	**$800.00**	$160.00	23.1%
Bangui II	WHO	1	$10.00	$50.00	12	**$720.00**	$17.56	14.3%
	KSPH	2	$10.00	$50.00	8	**$960.00**	$96.00	20.0%
	GIS	2	$10.00	$50.00	8	**$960.00**	$96.00	20.0%
	LQAS	1	$10.00	$50.00	8	**$480.00**	$96.00	20.0%
Begoua	WHO	1	$30.00	$50.00	14	**$1,120.00**	$27.32	12.5%
	KSPH	1	$30.00	$50.00	10	**$800.00**	$160.00	16.7%
	GIS	1	$30.00	$50.00	10	**$800.00**	$160.00	16.7%
	LQAS	1	$30.00	$50.00	10	**$800.00**	$160.00	16.7%
Bossembele	WHO	1	$30.00	$50.00	14	**$1,120.00**	$27.32	12.5%
	KSPH	2	$30.00	$50.00	10	**$1,600.00**	$160.00	16.7%
	GIS	2	$30.00	$50.00	10	**$1,600.00**	$160.00	16.7%
	LQAS	1	$30.00	$50.00	10	**$800.00**	$160.00	16.7%

Interviewer time:

HZ/District	Method	# Interviewers	Daily per diem	Daily honoraire	No of days	Cost	Cost Per Cluster	% Reduction
Ndjili	WHO	6	$10.00	$30.00	12	**$2,880.00**	$70.24	14.3%

	KSPH	8	$10.00	$30.00	8	**$2,560.00**	$256.00	20.0%
	GIS	8	$10.00	$30.00	8	**$2,560.00**	$256.00	20.0%
	LQAS	2	$10.00	$30.00	8	**$640.00**	$128.00	20.0%
Boko	WHO	6	$30.00	$30.00	14	**$5,040.00**	$122.93	17.6%
	KSPH	8	$30.00	$30.00	10	**$4,800.00**	$480.00	23.1%
	GIS	8	$30.00	$30.00	10	**$4,800.00**	$480.00	23.1%
	LQAS	2	$30.00	$30.00	10	**$1,200.00**	$240.00	23.1%
Bangui II	WHO	6	$10.00	$30.00	12	**$2,880.00**	$70.24	14.3%
	KSPH	8	$10.00	$30.00	8	**$2,560.00**	$256.00	20.0%
	GIS	8	$10.00	$30.00	8	**$2,560.00**	$256.00	20.0%
	LQAS	2	$10.00	$30.00	8	**$640.00**	$128.00	20.0%
Begoua	WHO	6	$30.00	$30.00	14	**$5,040.00**	$122.93	12.5%
	KSPH	4	$30.00	$30.00	10	**$2,400.00**	$480.00	16.7%
	GIS	4	$30.00	$30.00	10	**$2,400.00**	$480.00	16.7%
	LQAS	2	$30.00	$30.00	10	**$1,200.00**	$240.00	16.7%
Bossembele	WHO	6	$30.00	$30.00	14	**$5,040.00**	$122.93	12.5%
	KSPH	8	$30.00	$30.00	10	**$4,800.00**	$480.00	16.7%
	GIS	8	$30.00	$30.00	10	**$4,800.00**	$480.00	16.7%
	LQAS	2	$30.00	$30.00	10	**$1,200.00**	$240.00	16.7%

3. Coordination team costs: A sensitivity analysis was carried out by subtracting the cost of coordination -as it is likely that these costs were significantly higher costs than if carrying out a single method over a whole country (Table 18 in main report). This represents the field level costs for this study, and between DRC and CAR – likely represent the higher and lower costs that could be expected.

Costs of carrying out the study without taking into account coordination by method and site (Scenario 2)

HD/HZ	WHO	WHO-KSPH	GIS	LQAS
DRC Ndjili	6,734.47	7,287.81	7,307.81	2,421.84
DRC Boko	11,189.47	12,037.81	12,057.81	3,896.84
CAR Bangui II	8,793.47	11,083.80	11,503.80	3,742.12

CAR Begoua	13,886.24	8,016.90	8,226.90	5,217.12
CAR Bossembele	13,886.24	15,833.80	16,253.80	5,217.12

The study shows that when coordination costs are not taken into account, the difference in costs between sites in the same environment decreases. The costs for carrying out the study using the WHO method in Ndjili are estimated at USD 6734.47 and in Bangui II at USD 8793.47.

Ratio calculation to compare data collection methods

Ratios were calculated to compare costs between methods, using WHO as the standard. As all four methods produced similar coverage estimates, differing only in confidence interval widths, analysis included calculating a cost ratio of different methods, with the WHO method as the standard. Compared to the WHO method, the other three methods were less expensive to implement. For GIS and KSPH method, this was typically 23% to 54% of the cost of WHO, and LQAS was even lower overall, and between 18% to 20% of the cost of WHO. These estimates and ratios will vary when adjusting staff time, number of clusters and coordination costs as well as taking other special considerations such as flights and security.

Cost ratios based on actual expenditure by method and site

HZ/HD	WHO	KSPH	GIS	LQAS
DRC Ndjili	1.00	0.45	0.45	0.18
DRC Boko	1.00	0.54	0.53	0.20
CAR Bangui II	1.00	0.41	0.41	0.17
CAR Begoua	1.00	0.23	0.23	0.18
CAR Bossembele	1.00	0.45	0.45	0.18

Overall Cost per cluster

The sensitivity analysis was also done by country and overall. In general, the cost per cluster for the WHO method was the lowest with greatest variation by removing the coordination costs.

Overall Cost per cluster – by country

The sensitivity analysis was also done by country and overall. In general, the cost per HZ/HD for the WHO method was the highest with greatest variation by removing the coordination costs.

Cost by Cluster

Country	Sensitivity	WHO	KSPH	GIS	LQAS
DRC	Base case: As implemented	$924.24	$1,885.04	$1,859.39	$1,455.59
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$896.48	$1,718.94	$1,697.39	$1,351.09
		3.0%	8.8%	8.7%	7.2%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$218.58	$966.28	$968.28	$631.87
		76.3%	48.7%	47.9%	56.6%
CAR	Base case: As implemented	$1,823.34	$3,215.08	$3,263.80	$2,639.23
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,799.67	$3,074.95	$3,123.67	$2,550.29
		1.3%	4.4%	4.3%	3.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$297.28	$1,397.38	$1,439.38	$945.09
		83.7%	56.5%	55.9%	64.2%

	Sensitivity	WHO	KSPH	GIS	LQAS
Overall	Base case: As implemented	$1,463.70	$2,623.95	$2,639.62	$2,165.77
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$1,438.39	$2,472.28	$2,489.77	$2,070.61
		1.7%	5.8%	5.7%	4.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$265.80	$1,205.78	$1,230.00	$819.80
		81.8%	54.0%	53.4%	62.1%
	Range Between base and scenario 2	$266 - $1464	$1206 - $2624	$1230 - $2640	$820 - $2165

Cost by HZ/HD

Country	**Sensitivity**	**WHO**	**KSPH**	**GIS**	**LQAS**
DRC	Base case: As implemented	$37,894.04	$18,850.43	$18,593.93	$7,277.95
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$36,755.54	$17,189.43	$16,973.93	$6,755.45
		3.0%	8.8%	8.7%	7.2%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$8,961.97	$9,662.81	$9,682.81	$3,159.34
		76.3%	48.7%	47.9%	56.6%
CAR	Base case: As implemented	$112,135.37	$40,188.47	$40,797.47	$19,794.20
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$110,679.57	$38,436.87	$39,045.87	$19,127.20
		1.3%	4.4%	4.3%	3.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$18,282.97	$17,467.25	$17,992.25	$7,088.18
		83.7%	56.5%	55.9%	64.2%

	Sensitivity	**WHO**	**KSPH**	**GIS**	**LQAS**
Overall	Base case: As implemented	$60,011.76	$23,615.56	$23,756.56	$10,828.86
	Scenario 1: Adjusted for actual person-time (% decrease from base case)	$58,974.04	$22,250.52	$22,407.92	$10,353.06
		1.7%	5.8%	5.7%	4.4%
	Scenario 2: Removing coordination costs and adjusted for actual person time (% decrease from base case)	$10,897.97	$10,852.02	$11,070.02	$4,099.01
		81.8%	54.0%	53.4%	62.1%
	Range Between base and scenario 2	$10898 - $60012	$10852 - $23616	$11070 - $23757	$4099 - $10829