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Systemic analysis of bottlenecks in routine EPI coverage vaccination among children aged 0–23 months in the health areas of the Mumbunda Health District: a cross-sectional mixed-methods study

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Abstract

Background

Immunization is one of the most cost-effective public health interventions and plays a vital role in reducing infant mortality. However, routine immunization coverage remains suboptimal in the Democratic Republic of Congo, including Lubumbashi, despite progress since the establishment of the Expanded Program on Immunization (EPI). This study aimed to: *(i)* Identify the bottlenecks in immunization coverage in the health areas of the Mumbunda DH, in Lubumbashi; *(ii)* Identify the root causes of these bottlenecks; and *(iii)* prospects for strengthening routine EPI coverage in the HA of the Mumbunda District Health.

Methods

A cross-sectional mixed-methods study using a sequential explanatory design was conducted in the Mumbunda Health District between May 2025 and August 2026. Bottlenecks were analysed using an adapted conceptual model based on the WHO's four health-system functions (2000). The quantitative component constructed bottleneck scores and profiles, while the qualitative component analysed data from semi-structured interviews using the systematic thematic analysis approach developed by Naeem et al. (2023).

Results

A total of 45 healthcare providers from 29 first-level health services (FLHS) across 15 Health Areas participated in the quantitative component, and seven Health Area Nurse-in-Charge for Health Areas participated in the qualitative component. Most quantitative participants were women (64.4%), and their mean length of service was 14 ± 9.7 years. The main bottlenecks identified were in stewardship functions [8.33% (IQR: 0–42%)] and funding. [(21% (IQR: 7–36%)]. Qualitative analysis identified informational and territorial fragility of the EPI, weak ownership of peripheral planning, non-institutionalized adaptive governance and underfunded peripheral operational capacity as major root causes.

Conclusion

The main bottlenecks identified were in the stewardship and financing functions. These two functions thus become the primary levers for strengthening routine immunization coverage in Lubumbashi.

Introduction

Vaccination is one of the most cost-effective public health interventions and is essential for preventing disease and reducing mortality. Since the World Health Organization (WHO) established the Expanded Programme on Immunization (EPI) in 1974, substantial progress has been made in reducing the burden of vaccine-preventable diseases (1, 2). However, in 2023, 14.5 million infants had not received the first dose of the diphtheria, tetanus, and pertussis vaccine, and 6.5 million were only partially vaccinated. Many of these children lived in ten countries, including the Democratic Republic of Congo (DRC) (3). The continued presence of zero-dose and under-vaccinated children underscores the need to identify the bottlenecks that limit immunisation coverage (4, 5).

Studies explicitly examining these bottlenecks remain limited and have focused primarily on two of the four essential functions of the health system defined by the WHO (WHO, 2000): service delivery (6–8) and financing (9–11). One of these studies was conducted in the DRC (11). Studies in Ghana, Malawi, and Pakistan have highlighted territorial disparities, low community involvement, high dropout rates, shortage of trained staff, limited numbers of functional service delivery points, and unclear allocation of roles among actors (6–8). Other studies have reported fragmented responsibilities, weak coordination between planning and budgeting, low funding allocations, and delays in disbursement (9–11). These findings shows that bottlenecks are multidimensional, but their interactions within the health system remain insufficiently analyzed at the peripheral level.

Despite efforts to strengthen routine immunization through the 2020–2024 comprehensive Multiannual Plan, the Mashako Plan, and the 2025–2030 National Immunization Strategy, this gap persists in the DRC (12) ; (13). According to the 2023–2024 DRC Demographic and Health Survey (DHS-DRC), only 21% of children aged 12–23 months had received all core antigens, while 23% had received no vaccines (14). This shortfall sustains immunity gaps and contributes to recurrent vaccine-preventable diseases, including measles, polio, and yellow fever (15). On the supply side, only 66% of health facilities offered all vaccines in 2022, and the mean operational capacity score for immunization was just 51% (15).

EPI performance is further complicated by the discrepancies between administrative and sociological coverage derived from population surveys. While successive national surveys have reported coverage below target levels, administrative data often report rates that meet or exceed them (13, 14). This discrepancy is particularly apparent in the Mumbunda Health District, where administrative coverage for the district was reported at 111% in 2025, with market variations by antigen: 121% for BCG, compared to 78% for Rotarix and 72% for the yellow fever vaccine (16). This paradox extends beyond the Mumbunda Health District and raises questions about the capacity of local health systems to generate reliable information, identify under-vaccinated populations, plan activities and mobilise the resources required. The analysing of the Mumbunda Health District may therefore provide insights into other local systems in which high administrative coverage, sometimes exceeding 100%, coexists with lower coverage estimates from population-based surveys.

In the DRC, the health system is organised into three levels: central, intermediate and local. The local level is organised around the health zone, referred to internationally as a Health District, and is led by a management team (17). This team coordinates and manages the health district, including efforts to

improve services coverage and quality, particularly for maternal and child health, to organise the functioning of the first-level health services (FLHS) and the General Referral Hospital as the second-level health services, and to promote community participation (17–19). Each FLHS provides a Minimum Package of Activities to a population of approximately 10,000 people with a geographical area of 5 to 8 km² known as a 'health area' (HA) (20, 21). In urban settings, however, regulatory oversight is challenged by the proliferation, fragmentation and commercial diversity of healthcare providers, exposing populations to weaknesses in local health systems (22, 23). The resulting plurality of actors is particularly important at the frontline, where private providers operate alongside public and faith-based services, creating major challenges for regulation and coordination (24). Within an HA, the main FLHS acts as an interface between the health district, satellite FLHS and the community.

Using a systems perspective, we considered immunization coverage to be an intermediate goal of the EPI at the local level, viewing the health district viewed as a complex adaptive system within the health system (25, 26). Immunization coverage therefore reflects the delivery of immunization services arising from interactions among human, material, logistical and informational resources, financing, and stewardship, within a given context (25, 27). A bottleneck was defined as a constraint that limits achievement of immunization coverage targets in one or more of the four essential functions of the health system: stewardship, financing, resource generation, and service delivery. As they are situated at the interface between the health district and the community, primary care nurses are uniquely positioned to identify these constraints and their interactions.

This study aimed to identify, according to the perceptions of the nurses providing care, the bottlenecks in routine EPI vaccination coverage among children aged 0 to 23 months, their root causes and prospects for strengthening routine EPI coverage in the HA of the Mumbunda DH.

Methods

Type of study

This study was conducted within the field of health policy and systems research and was informed by the critical realism paradigm. It used a cross-sectional mixed-methods study (28–30), integrated quantitative and qualitative components through a sequential explanatory design (QUAN→QUAL). The cross-sectional design was selected because it enables a phenomenon to be explored, described and explained at a specific point in time(29). The overall study ran from May 2025 to August 2026 taking place from January to June 2026. The quantitative component took place from 28 January to 14 March 2026. Data collection for the quantitative component took place from 28 January to 14 March 2026, and the qualitative component was conducted from May to June 2026.

Study environment

This study was conducted in the Mumbunda urban health district in Lubumbashi, Haut-Katanga province, RDC. Created following the division of the Lubumbashi health district in 2006, Mumbunda covers an estimated area of 72 km² (16, 31) (Fig. 1, (32)). Demographic data indicate a gradual increase in the district population, projected at 568,357 inhabitants in 2025 and 624,467 in 2026. Children under five years of age represent approximately 4% of the total population (about 24,979 children), constituting an important target group for maternal and child health interventions. The Mumbunda Health District comprises 30 HAs and 186 health facilities. Of these, 142 are integrated into the national DHIS2 health information system and 98 appear on the official Health District lists. These facilities include eight referral health centres, four state-run health centres, 168 private health facilities and two faith-based health facilities. Their geographical distribution is uneven, with greater concentration in highly urbanised and densely populated areas, while some peripheral areas remain relatively underserved (16). For prevention services, 142 facilities organise pre-school consultation and vaccination services. However, access to vaccines remains unequal across different geographical areas. In 2025, the reported administrative vaccination coverage rate for EPI antigens was 111% (16).

Unit of analysis

The units of analysis are the Preschool Consultation services, specifically the vaccination component, of the chosen health district's FLHS.

Conceptual model

According to the WHO (25, 33), we considered "immunization coverage" to be part of the local health system. As such, coverage is simply a state of achievement of "immunization service delivery" within a local health system, resulting from "human", "material", "logistical," and "informational" resources, supported by funding and managed by stewardship. All of this is based on the values and principles guiding the EPI (20). The conceptual model is as follows (Fig. 2).

The context assessment will be addressed in a separate article. At the quantitative level, we utilised the conceptual model by breaking down each function of its functions into sub-functions/pillars, then these into evaluation domains and finally the evaluation domains into indicators and/or items, with two indicators and/or items per evaluation domain, based on the principle of balance (34). These indicators and/or items are adapted from those in the literature (13, 34, 35). Regarding the qualitative (QUAL) level, in accordance with the protocol for mixed-methods studies with an explanatory design, the QUAN guided the selection of questions for the interview guide. We used a root cause analysis approach, inspired by the "five whys" method but incorporating a systems thinking perspective (36). This approach employed progressive prompts adapted to the participant's responses in order to explore the root causes of each identified bottleneck.

Study population

The population under study comprises all nurses, Health Area Nurse-in-Charge (HA-NIC), Facility Nurse-in-Charge (F-NIC) and nurses working in the selected HAs, including providers involved in pre-school consultation and routine immunisation activities within FLHS.

Sampling

For the quantitative component, sampling was conducted in three successive stages. HAs were selected by non-probability convenience sampling, while FLHS within the selected HAs were sampled by quota. The FLHS sample size corresponded to 30% of the 98 operational FLHS reported as integrated into DHIS2 and appearing on the official Health District lists (n = 29.4) (37). Eligible FLHS had to be operational within an HA, appear on the official HD lists, and have managers and vaccination staff who provided free, informed and written consent to participate. FLHS were also selected according to the following HA/FLHS profiles (16): good access/good use; good access/poor use; poor access/good use; and poor access/poor use. Sampling of healthcare staff involved in pre-school consultation and vaccination was non-probability and exhaustive within the included HAs and FLHS. Eligible participants were healthcare professionals involved in vaccination who provided free, informed and written consent. Vaccination documents were also sampled exhaustively using document-review procedures, including all available records meeting criteria related to antigen, period, geographical area and FLHS level. Relevant vaccination documents were identified in each selected FLHS and at Health District level.

For the qualitative component, participants were selected purposively. Findings from the quantitative component informed the categories of participants selected for the qualitative phase. Recruitment proceeded flexibly, iteratively and cumulatively in accordance with the principle of data saturation, moving across units of analysis until seven participants had been included. Eligible participants were healthcare professionals serving as HA-NICs of HAs who provided free, informed and written consent to participate .

Data collection

The quantitative component used the following data-collection methods: (i) a face-to-face questionnaire administered during a single visit; (ii) structured observation using a guide to verify the presence of elements reported by participants; (iii) structured extraction of documentary data using a data-extraction form; and (iv) direct observation of vaccination activities during investigators' visits. The latter included open, unstructured observations alongside the use of a structured direct-observation guide. The study therefore drew on primary data from respondents and secondary data from available documentation, collected by four investigators (CKD, ASS, IKO and PPM). Investigators prepared field reports and summaries of their observations and impressions to support interpretation of the findings. Data-collection tools were pre-tested in the Kisanga Health District, and feedback from this exercise was used to refine them. The tools were subsequently contextualised by a consultant (ASS, Field Epidemiology and Laboratory Program), a member of the District Health Management Team (DHMT), and two HA-NICs from the Kisanga Health District, and were validated by AMN and DCK. Internal consistency of the groups of dichotomous items corresponding to the four health-system functions was assessed using the Kuder-Richardson 20 (KR-20) coefficient. KR-20 values were 0.835 for stewardship, 0.721 for financing, 0.674 for resource generation and 0.830 for service delivery.

For the qualitative component, data consisted of participants' accounts and perspectives. Semi-structured individual interviews lasted between 40 minutes and 2 hours. Findings from the quantitative component informed the themes and sub-themes explored in the qualitative phase. The principal investigator conducted the interviews face to face using an interview guide. Interviews were iterative and, when necessary, were repeated with the same participant to clarify, supplement or specify information. Interviews were audio-recorded using an Android phone recorder application after written informed consent had been obtained. Data collection continued until analytical saturation was reached (n = 7), defined as the point at which further coding and analysis no longer generated substantial new codes, themes, patterns or relationships that could alter understanding of the bottlenecks under investigation (38). In accordance with Naeem et al. (2024), subsequent data primarily served to confirm, enrich or refine themes and relationships already identified (38).

Data analysis

Quantitative data were exported from the KoBoToolbox server in XLS format and subjected to exploratory, descriptive and univariate analyses. Initial data processing involved coding, entry and classification of data from the completed collection tools by function, sub-function and EPI evaluation domain at operational level using Excel 2010. Items and indicators with discrete responses were transformed into binary indicators ('no' = 0 points, corresponding to the presence of a bottleneck; 'yes' = 1 point). Questionnaire responses were analysed to identify common bottlenecks, defined as those reported by at least one respondent in each FLHS. Within an FLHS, an indicator was considered to represent the absence of a bottleneck when its value was at least 90%(39); values below this threshold were classified as bottlenecks (0). For supply-chain performance, the indicator was the proportion of orders received within 14 days or less (33), with a target of at least 90% (39). Findings from the other data-collection methods were then triangulated with the structured observation data.

For sociodemographic variables, descriptive analyses included absolute frequencies and percentages, measures of central tendency (mean, minimum and maximum) and dispersion (standard deviation). Bottlenecks were also profiled by function and sub-function across FLHS. For each sub-function or function, the score was calculated as the number of points obtained by an FLHS divided by the maximum possible score(34). Median scores were used to characterise bottleneck severity. Four-point sub-functions were classified as follows: no bottleneck (4 points), minor bottleneck (3), important bottleneck (2), or major bottleneck (0–1) (30); this classification was adapted for six- and 14-point sub-functions. For each function, the overall score was expressed as a percentage of the maximum possible score (34). Function and sub-function profiles and indicator/item performance scores were classified as follows: no bottleneck (≥ 80%), minor bottleneck (60–79%), important bottleneck (40–59%), or major bottleneck (< 40%). Analyses were conducted using Microsoft Excel 2019, Epi Info 7.2.2.6, IBM SPSS Statistics version 27, the Open Data Kit Collect mobile application and KoBoToolbox.

For the qualitative component, audio recordings were listened to repeatedly before being transcribed verbatim in Microsoft Word; interviews conducted in Swahili were subsequently translated into French. Data were analysed using the systematic thematic analysis approach described by Naeem et al. (2023) (41), undertaken manually with AI assistance (OpenAI, GPT-5.6, August 2026) (42).

Two authors (CKD and IKO) conducted the manual analysis, with GPT-5.6 used at selected stages in accordance with the AI-assisted thematic analysis approach described by Naeem et al. (2025). The final analysis presented in this manuscript was validated by two authors (AMN and DCK). In the Results section, each concept is presented with its corresponding themes, analytical propositions and illustrative verbatim quotations highlighting the explanatory mechanisms identified (43). Tools used included Microsoft Word, Excel 2019, VLC media player 3.0.21 Vetinari, the Android voice recorder and GPT-5.6 (OpenAI, August 2026).

Results

Profiles of respondents

For the quantitative component, Table 1 presents the sociodemographic characteristics of the 45 healthcare providers who participated in the study across the 29 FLHS of the 15 health area. The majority of respondents were female (64.44%), with an average age of 47 ± 7.9 years and an average seniority of 14 ± 9.73 years. The largest category of participants was that of undergraduate university graduates (A1, 62.22%), and 40% of them were nurses.

Table 1
Sociodemographic characteristics of respondents

Settings	Number of employees (n = 45)	Percentage
Sex		
Female	29	64.44
Male	16	35.56
Age (Mean ± SD)	47 ± 7.9 (22–59)	
Seniority (Average ± SD)	14 ± 9.73 (1–37)	
Level of education		
Undergraduate level (A1)	28	62.22
State Diploma in Medical Sciences (A2)	11	24.44
Second cycle of university studies (A0)	5	11.11
Short course in medical sciences (A3)	1	2.22
Function		
Nurse	18	40.00
Facility Nurse-in-Charge	13	28.89
Health Area Nurse-in-Charge	14	31.11

For the qualitative component (Table 2), seven participants were selected, including two men, all Health Area Nurse-in-Charge (HA-NIC). Their ages ranged from 34 to 55 years, with a median age of 45 years and an interquartile range of 40 to 50 years. Their length of service ranged from 10 to 27 years, with a median age of 19 years and an interquartile range of 17.5 to 22.5 years.

Table 2
Characteristics of the participants

Sex	**n = 7**
F	5
M	2
Seniority (Median, Interquartile range)	19 (17.5–22.5)
Age (Median, Interquartile Range)	45 (40–50)

Identification of bottlenecks in routine EPI vaccination coverage in the Mumbunda health district

Tables 3, Box 1 and Fig. 3 show that the stewardship function had a major bottleneck profile (median overall score: 8.33%; IQR: 0–42). The main bottlenecks were: (i) weak production and use of health information: problems with archiving forms in the health units; failure to hold data certification (monitoring) meetings; (ii) centralization of stewardship at the level of the main FLHS: failure to disseminate the HA microplan to satellite FLHS and concentration of strategic functions functions (planning, coordination) such as planning and coordination at the main FLHS; (iii) low community participation and weak

intersectoral collaboration: failure to hold integrated monitoring meetings; failure to disseminate (share) recovery plans (monthly, quarterly, semi-annual and annual reviews) to the community level; (iv) weak participation in stewardship and limited accountability: poor follow-up on recommendations from supervisions; (v) weak regulation of the supervision system: supervision by the DHMT supervision relatively present but unevenly distributed across health area (some health area are better supervised by the District Health Office (DHO) than others); absence of horizontal supervision of FLHS by the HA-NIC.

Table 3
Bottleneck profiles of FLHS according to the functions and sub-func

Function	Sub-function	HA 1		HA 2		HA 3		HA 4		HA 5		HA 6		HA 7	HA 8		H
		S	M	S	M	M	S	M	S	M	S	M	S	M	M	S	S
Stewardship	Strategic direction (/4 points)	1	0	0	2	0	0	2	0	2	0	2	0	3	2	0	0
	Tactical guidance (/4 points)	0	0	0	1	2	0	1	0	0	0	2	0	3	1	0	0
	Operational responsiveness (/4 points)	0	1	0	1	1	0	1	1	3	0	3	1	3	2	0	0
Total points (positive answers) obtained/12		**1**	**1**	**0**	**4**	**3**	**0**	**4**	**1**	**5**	**0**	**7**	**1**	**9**	**5**	**0**	**0**
Overall scores for the stewardship function (/100%)		**8.3**	**8.3**	**0**	**33.3**	**25**	**0**	**33.3**	**8.3**	**41.7**	**0**	**58.3**	**8.3**	**75**	**41.7**	**0**	**0**
Funding	Fundraising (/6 points)	1	2	1	2	2	1	3	1	4	1	3	2	3	3	0	1
	Pooling (/4 points)	0	0	0	2	0	0	1	0	2	0	1	1	1	0	0	0
	Payment (Purchase) (/4 points)	1	1	0	1	1	0	0	0	2	0	1	0	1	2	2	0
Total points (positive answers) obtained/14		**2**	**3**	**1**	**5**	**3**	**1**	**4**	**1**	**8**	**1**	**5**	**3**	**5**	**5**	**2**	**1**
Overall scores /100%		**14**	**21**	**7**	**36**	**21**	**7**	**29**	**7**	**57**	**7**	**36**	**21**	**36**	**36**	**14**	**7**
Resource generation	Human Resources (/6 points)	3	4	4	5	4	2	5	2	6	3	5	4	4	5	5	4
	Material resources (Infrastructure, Medical) Products, Vaccines & TecHA-NICologies) (/6 points)	3	6	4	3	6	2	5	2	3	4	6	3	4	5	2	2
	Logistics (/6 points)	2	2	0	2	2	2	2	2	4	2	1	1	3	2	0	1
	Informational (/6 points)	3	6	4	4	4	2	6	3	6	5	6	5	4	2	1	3
Total points (positive answers) obtained/24		**11**	**18**	**12**	**14**	**16**	**8**	**18**	**9**	**19**	**14**	**18**	**13**	**15**	**14**	**8**	**1**
Overall scores /100%		**45.8**	**75**	**50**	**58.3**	**66.7**	**33.3**	**75**	**37.5**	**79.2**	**58.3**	**75**	**54.2**	**62.5**	**58.3**	**33.3**	**4**
Provision of services	Concentration of care (/4 points)	3	4	3	4	3	3	4	3	4	3	4	4	4	4	4	4
	Accessibility (/14 points)	9	9	13	11	10	9	10	12	10	11	12	12	10	12	10	1
	Affordability and attractiveness (/4 points)	2	3	3	2	2	2	2	1	3	4	3	3	2	2	2	2
Total points (positive answers) obtained/22		**14**	**16**	**19**	**17**	**15**	**14**	**16**	**16**	**17**	**18**	**19**	**19**	**16**	**18**	**16**	**1**
Overall scores/100%		**63.6**	**72.7**	**86.4**	**77.3**	**68.2**	**63.6**	**72.7**	**72.7**	**77.3**	**81.8**	**86.4**	**86.4**	**72.7**	**81.8**	**72.7**	**8**

Function	Sub-function	HA 1		HA 2			HA 3	HA 4		HA 5		HA 6		HA 7	HA 8		H
		S	M	S	M	M	S	M	S	M	S	M	S	M	M	S	S

Legend: S: Satellite FLHS. M: Main FLHS. HA: Health Area

The financing function presents major bottlenecks [the median overall score for the financing function was 21% (7–36)]. Key bottlenecks included: (i) weak mobilisation of EPI financial resources: absence of dedicated EPI budget lines in microplans. limited transfer of state financial resources to health area; responsibility for financing is identified, but not translated into effective commitments; underdeveloped internal mechanisms for mobilizing resources (community or partners); very limited, or even absent, effective local contribution (financial or material) in some health area; (ii) weak and poorly structured pooling of resources: a dominant dependence on external or state funding; poorly formalized and documented financing arrangements for vaccination activities; a lack of budgetary evaluation mechanisms for EPI activities in the health area; (iii) low allocation of resources and inefficient procurement: constraining supply delays between ordering and receiving inputs for the EPI (fuel, logbooks, equipment) (Tables 3, Box 1 and Fig. 3).

Box 1. Bottlenecks in routine EPI immunisation coverage across the four health-system functions

I. Major bottleneck in the EPI stewardship function

Weak production and use of health information

• Near-generalised lack of regular submission of Form 1 reports to the District Health Office (DHO) within the Health Areas, or inadequate archiving of these forms in first-level health services (FLHS);

• Infrequent data certification meetings.

Centralisation of stewardship at the level of the main FLHS

• Limited dissemination of the microplan to the main FLHS;

• Strategic functions, particularly planning and coordination, remain concentrated.

Low community participation and weak intersectoral collaboration

• Limited organisation of integrated monitoring meetings;

• Limited dissemination of corrective action plans to the community level.

Limited participation in stewardship and weak accountability

• Low participation of Health Area nurses-in-charge in monthly review meetings;

• Weak follow-up of recommendations arising from supervisory visits.

Weak regulation of the supervision system

• Supervision by the District Health Management Team (DHMT) is relatively frequent but unevenly distributed, with some Health Areas receiving more supervision from the DHO than others;

• Absence of horizontal supervision of FLHS by Health Area nurses-in-charge.

II. Major bottleneck in the EPI financing function

Weak mobilisation of financial resources for the EPI

• Absence of a dedicated EPI budget line in microplans;

• Lack of transfer of government financial resources to Health Areas;

• Responsibility for financing is identified but is not translated into effective financial commitments;

• Poorly developed internal resource-mobilisation mechanisms involving communities or partners;

• Effective local contributions, whether financial or in-kind, are very limited or absent in some Health Areas.

Weak and poorly structured pooling of resources

• Heavy dependence on external or government funding;

• Financing arrangements for immunisation activities are poorly formalised and documented;

• Absence of mechanisms for evaluating EPI budget implementation within FLHS.

Inefficient resource allocation and procurement

• Long and constraining lead times between ordering and receipt of EPI supplies, including fuel, registers and equipment.

III. Important and minor bottlenecks in the EPI resource-generation function

Shortcomings in the availability and management of human resources

• Inadequate workforce planning and allocation: insufficient assignment of staff to EPI activities in several FLHS, combined with workload overload and concentration of EPI activities among a limited number of health workers;

• Unequal opportunities for health-worker capacity building;

• Suboptimal use of human resources: limited availability of monitoring tools, including antigen monitoring charts.

Structural constraints affecting material resources and the cold chain

• Insufficient availability of functional refrigerators in some first-level health services;

• Generally satisfactory technical capacity, but limited translation into the effective availability of essential inputs;

• Limited existence and implementation of equipment maintenance plans;

• Inconsistent waste management, with potential health and environmental risks;

• Irregular availability and updating of stock-management tools;

• Irregular monitoring of cold-chain temperatures, particularly in some FLHS.

Weak vaccine logistics performance

• Inadequate anticipation of needs, including quantification and order planning;

• Low proportion of complete and timely deliveries;

• Absence of documented vaccine losses;

• Orders that are sometimes excessive or poorly aligned with actual consumption.

Weaknesses in the EPI health information system

• Incomplete training of staff in the correct use of data-management tools;

• Variable availability of guidance for completing these tools.

IV. Minor bottlenecks in the EPI service-delivery function at Health Area level, with persistent constraints

Generally satisfactory technical quality, although weakened by vaccine-safety shortcomings

• Vaccine-safety shortcomings: limited availability of tools for adverse events following immunisation (AEFI) surveillance and irregular reporting of cases.

Barriers to access to services

• Informal direct payments in several FLHS;

• Costs that are sometimes perceived as unaffordable by households, resulting in delayed visits or discontinuation of care;

• Service opening hours that are sometimes poorly aligned with users' socioeconomic circumstances;

• Domestic and income-generating activities among mothers that may constrain attendance at immunisation services.

The resource generation function has significant bottlenecks [the median overall score for this function is 58.3% (45.8–67.7)]. The main bottlenecks were: (i) shortcomings in the availability and management of human resources, including inadequate staff planning and allocation, insufficient assignment of staff to EPI activities, work overload and concentration of EPI tasks among a limited number of health workers, together with unequal opportunities for continuing professional development; (ii) suboptimal use of human resources, including limited availability of monitoring tools such as antigen tracking charts; (iii) structural constraints affecting material resources and the cold chain, including shortages of functional EPI-dedicated refrigerators and adequate refrigerator capacity in some FLHS, lack of electricity or solar power in some settings, limited development and implementation of equipment-maintenance plans, inconsistent waste management, irregular availability and updating of stock-management tools, and irregular cold-chain temperature monitoring; and (iv) weak vaccine logistics, including limited control of antigen targets, a low proportion of complete and timely deliveries, undocumented vaccine losses and observed stock-outs (Tables 3, Box 1 and Fig. 3).

The bottlenecks in the EPI service delivery function are minor [(The overall median score for this function is 72.7% (72.7–81.8)], but nevertheless present some constraints: (i) weaknesses in vaccine safety, particularly limited availability of adverse events following immunisation (AEFI) forms and irregular case notification; and (ii) barriers to access, including informal direct payments in several FLHS, costs perceived by some households as unaffordable and leading to postponement or discontinuation of visits, opening hours that were sometimes poorly aligned with users' socioeconomic circumstances, and constraints related to mothers' domestic or economic activities (Tables 3, Box 1 and Fig. 3).

Identifying the root causes of bottlenecks in routine EPI immunization coverage in the Mumbunda health districtH

The qualitative findings are organised according to the conceptual model of the four health-system functions.

Function 1: Stewardship / Piloting

Informational and territorial fragility of the EPI

Interviews with HA-NIC of the health area show that Form 1 forms are generally produced and sent to the CODH, but their local archiving often depends on the resources available in the health area.

"If I finish, I make a photocopy. Sometimes I make a photocopy, sometimes I take the photos from my phone. If I don't have the money to photocopy them, then I have others on my phone, and I photocopy others." **HA-NIC 1**

Some HA-NIC of the health area explain that previously, forms included stubs, making it easy to keep a local record. With loose-leaf paper forms, archiving becomes an additional responsibility for the HA-NIC department, which often lacks sufficient resources.

"We used to do archiving quite often. When we had our form with the stubs, it was easy to archive. […] But this time, we sometimes get a document that we have to photocopy ourselves. […] Since we started in January, I've archived some forms, but not others because of this photocopying problem and the lack of stubs for form 1." **HA-NIC 3**

In some health area, not all FLHS regularly submit their forms, even though they continue to vaccinate.

"Here, at my place, I can say that as many as 60% of the forms are sent to the CODH. *Among the seven FHSs, there are perhaps four FLHSs that regularly submit their Form 1s. […] The others, sometimes, they only make the signs without reporting the vaccination data. But they do vaccinate."* **HA-NIC 7**

HA-NIC 5 presents a contrasting case, characterized by relatively complete archiving of forms and more regular use of data. The data is also analyzed against targets and reported in a dashboard.

“When they come to the central office, they are sent to me. That’s why, for my records, you’ll find all the Form 1s. […] If we haven’t reached that objective, we’ll look for the causes and possible solutions. […] After the analysis, we create the dashboard that’s over there.” **HA-NIC 5**

Added to this is the territorial ambiguity of the data, when children from other health area or other district health are included in the same reports without clear distinction.

"The vaccination team doesn't come, I'm on the road. At the end of each month, I go to Gécamines to collect data and ask them about any difficulties they're having." **HA-NIC 5**

“In our reports, we no longer really need to know who came from outside the HA, *who came from outside the district health. We put everyone in a single basket. […] For the BCGs, we go well beyond the target. You can reach 140%, 145%.”* **HA-NIC 4**

Poorly appropriate peripheral planning

Interviews with HA-NIC staff holding health area positions show that the EPI microplan exists, but that it is often developed or validated with strong involvement from the CODH. The participation of satellite social enterprises, particularly private ones, remains limited.

“Our health area micro-plan often involves working together with the district health management team. […] No, not satellite FHSs, no. Just us. Me, HA-NIC, F-NIC and Chairman of the Health Area Development Committee.*”* **HA-NIC 1**

However, the case of HA-NIC 5 qualifies the low participation of peripheral actors at the time of the development of the microplan.

“Normally, in the microplan, you first have to raise awareness among the FLHS. […] Normally, we work with them and the Chairman of the Health Area Development Committee too, who are familiar with the situation in relation to the block. […] They can send me the data I need to put in the microplan.” **HA-NIC 5**

In several HA, the microplan remains stored at the mother center, at the HA-NIC or at the CODH level. They sometimes only receive verbal or partial information during monitoring meetings.

*“No, it will always stay here. It will remain at the main center. […] In the monitoring meeting, we will communicate our population to the satellite FLHSs. […] Our copy must always remain at the main center.”***HA-NIC 2**

*“I have to tell the truth, because the microplan only stays within HA-NIC. It stays with HA-NIC and at headquarters. […] But in private social enterprises, they don’t have a microplan.”***HA-NIC 5**

Non-institutionalized adaptive governance

The interview excerpts show that HA-NIC staff do not remain passive in the face of difficulties. They organize meetings, follow up with the FLHS team, use the telephone, transmit recommendations via WhatsApp, supervise when possible, and seek solutions to identified problems. This local governance demonstrates a strong capacity for adaptation.

'll find my recommendations. And each time, if there's a recommendation, I send it directly to my health area group." **HA-NIC 4**

However, this governance often relies on informal arrangements. Recommendations are sometimes verbal, kept in personal notes, or transmitted by telephone.

*"It's verbal... by phone, sometimes during the meeting. If they come. If they don't come, by phone."***HA-NIC 1**

Faced with constraints of time, transport and staff availability, some HA-NIC departments are also developing forms of local innovation, including remote meetings or exchanges.

“I thought to myself: okay, I’ll adapt. I called my friends on the phone. I said: we’re going to meet on the phone. Open your phones, connect. And when I presented the results of my meeting on WhatsApp, […] they appreciated me even more.” **HA-NIC 4**

In contrast to the essentially informal practices observed in several health area, HA-NIC 5 describes relatively more structured local governance mechanisms.

"For us, they are followed up in the Executive Committee meetings. The recovery plans in relation to the review, we come with these, we analyze them in the Executive Committee meetings, the meetings of the heads of departments. We analyze them with the medical director. We look for the weaknesses, the points for improvement, what is not working and why." **HA-NIC 5**

HA-NIC 5 also indicates that the recommendations left during supervisions are reviewed and verified during subsequent visits.

*“When they come to follow up, before starting the meeting they came to hold, they must first review the points they left, to see if we have already made improvements. […] We take the supervision records, we review the points that have been improved. […] We reread the weaknesses, we put them into action.”***HA-NIC 5**

Horizontal supervision of satellite FLHSs is recognized as necessary, but it remains difficult to ensure regularly due to workload overload, lack of time and lack of dedicated resources.

"Yes, from time to time, but with work and the workload. To say that I do it regularly, I don't. I might leave when things aren't going well at a particular center." **HA-NIC 6**

Function 2: Financing

Underfunded peripheral operational capacity

The interview excerpts show that vaccination activities can be planned, integrated into the microplan, or discussed in meetings, but that the corresponding financial resources do not always reach those responsible for implementing them. At HA-NIC 1, funding for routine immunization appears to be almost non-existent at the health sector level.

"No, there isn't one. Well, it's not planned. [...] It doesn't exist. So, that's what you just saw. It doesn't exist, it's complicated." **HA-NIC 1**

The same participant points out that state resources are not being perceived at the peripheral level to support vaccination activities.

"No, no. No, that's not happening. […] I didn't know there were state resources involved in vaccination activities." **HA-NIC1**

HA-NIC 4 clearly demonstrates this disconnect between budget planning and actual access to resources:

"There's the budget page. And that budget isn't at our level. It's at the zone level. Even if the money will come. […] If I say, for example, I need $10 every month to attract these small activities, am I going to find that $10 in the center's coffers? No." **HA-NIC 4**

Expenses related to vaccine recovery or the supervision of satellite FHSs are often borne locally. HA-NIC 1 directly reflects this situation.

"It's our money. For example, here, it's my turn to get the vaccine. I'm paying for it." **HA-NIC 1**

HA-NIC 3 describes the same mechanism in the supply chain. While the CODH is supposed to deliver the vaccines to the HA, the HA itself must go down, submit the requisition, wait for the collection day, and pay for the transport .

"When it comes to the EPI, we go down ourselves. We pay for our own transportation. We leave. We leave the requisition. We wait for the recovery days. We leave. We recover. We bring back. […] We are the ones who pay for our own transportation. But they are supposed to bring the vaccines here to us." **HA-NIC 3**

HA-NIC 5 also reports that routine activities are much less supported than campaigns.

"Even though we discussed this issue, there hasn't been any change... The budgets, at least during the campaign, but for weekly activities, there's nothing, Dad. There's nothing." **HA-NIC 5**

Peripheral underfunding also affects the supervision of satellite first-level health services.

"These movements I'm making here, I'm making them with my own resources… I make them when I have the resources. When I don't, I don't make them. If I have to use transportation, it has to come from my own pocket. If I have to use communication, it has to come from me… We're sent on supervision without any resources." **HA-NIC 4**

The interviews also reveal that the official free nature of vaccination can be undermined by peripheral costs. While the vaccination itself is free, certain aspects of the service can generate expenses: photocopying the vaccination card, weighing the patient, transportation, or small local contributions. These costs are often used to maintain the minimum operational requirements of the service, but they can also create a perception of payment around an activity that is supposed to be free.

"Vaccination is normally free... Since we're combining vaccination and weighing, we're charging for the weighing... The money from weighing helps us cover the expenses related to the vaccines." **HA-NIC 6**

Function 3: Resource Generation

Logistics vulnerability and differentiated cold chain

The interviews show that vaccine availability does not necessarily mean their effective availability locally, at the right time, and under safe conditions. Some health districts do not have EPI-approved refrigerators and must resort to external or informal solutions. HA-NIC 1 clearly describes this situation in a newly established health district, where EPI activities are organized without the necessary logistical equipment being fully available:

"We don't have refrigerators. The newly formed HA units don't have refrigerators. […] They're not equipped yet. We only told you that you'll be organizing the activities. […] For us, from health area X, I'm putting this [satellite FLHS]. It's a refrigerator that isn't approved by the EPI." **HA-NIC 1**

The same constraint arises at HA-NIC 7, where the lack of a refrigerator necessitates external storage of vaccines in a nearby area. This arrangement requires travel, transportation costs, and the retrieval of vaccines according to the session days.

"…No, we don't have that [a refrigerator approved by the EPI]. The new health area units are cut up. We keep the vaccines in the neighboring health area unit … We take the transport. The transport needs to be given to the community relay. … After the vaccination, we take everything again, put it back where we store it… We pay for the transport." HA-NIC 7

Some healthcare facilities have a functional cold chain. HA-NIC 4 presents a more favorable case, with a certified refrigerator, sufficient capacity, and a dedicated solar kit:

“The refrigerator is sufficient. […] It even covers our campaign vaccinations… it’s approved. […] Our boss, the BDOM, provided us with a substantial solar power kit. […] We equipped the refrigerator itself with a solar kit. And this solar kit isn’t connected to anything else except the refrigerator.” **HA-NIC 4**

In several health areas, when supplies are delayed or when vaccines are not available in sufficient quantities, the HA-NIC departments develop local arrangements, including borrowing from neighboring areas.

"If you're not clever, you risk causing further problems during other sessions. [...] I can contact my colleague at such-and-such heakth area. You can get something for me to cover the session. As soon as I receive it, I'll return." **HA-NIC 3**

Concentrated vaccination expertise and human overload

The interviews show that staff availability is not limited to the number of staff present in a facility. It also depends on their stability, training, proficiency with EPI tools, and their ability to conduct sessions despite other center duties. In some social service agencies, staffing levels are insufficient, especially in private and satellite social service agencies. HA-NIC 3 clearly describes this difficulty, demonstrating that the financial constraints of private social service agencies limit staff recruitment, which directly impacts EPI activities.

“…No, no. It’s really insufficient. […] In the private social economy, there are certain obligations. You can’t just hire a lot of people. You’ll pay them for it. In the EPI, it’s suffering. […] With the satellites, if one of the people who are there isn’t there, the activity won’t happen.” **HA-NIC 3**

Overload also appears in the parent centers. HA-NIC 4 explains that agents are involved in several activities simultaneously, making it difficult to assign a service provider exclusively to the EPI.

"There are many activities that require a lot of money at the same time. So much so that you can't reassign an agent from one position to another task right now. It even happens to us here. You saw when you came here, you didn't find me. And since you've been with me here, you've seen how many times people have come to ask for your help." **HA-NIC 4**

However, the situation reported by HA-NIC 5 presents a contrasting case in quantitative terms. HA-NIC 5 indicates that the various functions required for a vaccination session can theoretically be distributed among several providers.

“Normally, for a vaccination session, there should be four people. You're not the one who's going to weigh people or give the vaccinations, no. There are those who register, those who vaccinate, those who weigh people, and those who administer the vaccine. […] Here, whether it's doctors or nurses, there are enough of them.” **HA-NIC 5**

In some health area, several people may be present, but not all of them really master the EPI procedures.

"At our place, we vaccinate in groups of three, but I have to be there for the vaccination to take place." **HA-NIC 6**

Training is another important dimension of this vulnerability. Interviews indicate that some staff members have received training, but that the training is outdated, irregular, or replaced by occasional briefings. Three HA-NIC reported it as follows:

"There are people who are trained, but it's training that's more than two years old. Those who are trained, were trained more than two years ago. The real training, to put yourself in this position, this is how we vaccinate, this is how we manage, this is, this is, this is, this is more than two years old." **HA-NIC 4**

“They are not trained, they are briefed. […] There are only briefings. […] When I started, I had never been trained. This is the first time I have done a briefing .” **HA-NIC 5**

“I was briefed at the Kisanga Security Zone; all the HA-NIC staff were seated and everything was explained. That was over 10 years ago.” **HA-NIC 6**

Function 4: Service Delivery

Precarious community dependency

Interview excerpts show that community health workers contribute to raising awareness, reminding mothers, identifying children who have not received the first dose, catching up on vaccinations for under-vaccinated children, and directing families to vaccination sessions. However, this contribution remains fragile because it largely depends on volunteer work, sporadic motivation, the availability of community health workers, and the limited support they receive.

“During the vaccination session, we need a community health worker to accompany us. […] the unavailability of community health workers. […] they don't raise awareness, there is low participation of mothers in vaccination.” **HA-NIC 1**

"If we see that the data is very low compared to our population, we ask the Community health workers, or ourselves, to raise awareness among mothers." **HA-NIC 2**

HA-NIC 5 shows that relays also play a central role in actively searching for zero-dose and under-vaccinated children.

“The communities really have a lot of work to do in the community. […] He goes out into the field two to three times a week to pick up children who have received no doses and are under-vaccinated.” **HA-NIC 5**

Socio-territorial accessibility and fragile vaccine acceptability

The interviews first revealed that missed opportunities are a significant mechanism of under-vaccination. When a child is in contact with the health service but is not vaccinated immediately, the family must return later. However, this return is not always guaranteed.

“Here in our neighborhood, we have a lot of people who haven't received a dose and are under-vaccinated. Many people are moving here. […] When they arrive, they bring their children for checkups; when they ask about their vaccination status, we find out the child isn't vaccinated. Since we're implementing the OVM strategy, and we don't store vaccines here, we ask families to come back on Wednesdays. ” **HA-NIC 7**

Conversely, HA-NIC 4 shows that vaccination at all contacts can reduce missed opportunities when vaccines are available and when technical rules permit.

"Regardless of the day the person came, we vaccinate. [...] No. Except for the vaccines you mentioned. [...] Vaccines like VAA, BCG. [...] you can't open a vial for just one child." **HA-NIC 4**

Accessibility also has a financial dimension. Vaccination is officially free, but certain additional costs can influence families' decisions, particularly in disadvantaged neighborhoods.

“Here, vaccination is free. Even if you ask for 1000 FC, maybe 5 out of 10 will pay, the others won't. In this neighborhood, if you put pressure on them, you'll lose them.” **HA-NIC 7**

Vaccine acceptability is also undermined by beliefs, rumors, and cultural representations.

“There are no identified pockets of resistance. These are isolated instances. […] There are those who tell you that vaccines harm children’s health. […] You go into another household and they tell you that your vaccine will prevent our children from being born. […] Our children will be sterile.” **HA-NIC 4**

HA-NIC 7 highlights another form of fragility in acceptability, linked to residential mobility, traditional therapeutic practices and language barriers.

“We have a difficulty, since it’s a neighborhood of newcomers… We’re used to the ‘ mishi ’ roots, we don’t get vaccinated. When we organize campaigns, there has to be someone from Kasai, someone who speaks Tshiluba. At least he can manage to convince them, but for someone who speaks Swahili, it’s very difficult. Sometimes you arrive in a household and they don’t know Swahili.” **HA-NIC 7**

HA-NIC 7 describes rain and flooding as significant obstacles, particularly for households living outside the health zone or area.

“Here, there’s also the problem of accessibility during the rainy season. We can’t get through… The facility is in the Potager village; if it rains, you should know that you won’t be able to vaccinate, at least not those outside the health area or outside the health zone… A few, because here, there’s flooding. Even we can’t get out.” **HA-NIC 7**

Discussion

This study aimed to identify, from the perspectives of nurses involved in care delivery, the bottlenecks in routine EPI immunisation coverage among children aged 0–23 months, their root causes, and prospects for strengthening routine immunisation coverage in the HAs of the Mumbunda Health District. Quantitative findings showed major bottleneck profiles in stewardship and financing. Qualitative analysis identified eight interdependent root causes related to information, planning, governance, financing, logistics, skills, community participation and vaccine accessibility. The study included a range of participant and service profiles, including established and newly created HAs and both public and private FLHS, thereby strengthening the contextual breadth of the findings.

Stewardship showed the greatest deficit, with a median score of 8.33% (IQR: 0–42%). The interviews helped interpret this profile through three interdependent mechanisms: informational and territorial fragility, weak ownership of the microplan and insufficiently institutionalised adaptive governance. Informational fragility extended beyond poor maintenance of tools. Because photocopying resources were limited, some HNs archived forms on their phones; in one HA with seven FLHS, only four reported regularly even though all were vaccinating. Similar information-system weaknesses have been documented by Harrison et al. (2020) and Ssegujja et al. (2025) and may affect administrative coverage estimates, planning and monitoring (44, 45). The interviews particularly highlighted difficulties experienced by satellite FLHS, which provided vaccination services without being systematically involved in microplanning or holding a copy of the microplan. As reported by Mafigiri et al. (2021) and Salisbury et al. (2024), the problem may lie less in the existence of a plan than in its ownership by those responsible for implementation (46, 47). HNs attempted to compensate through telephone calls, WhatsApp exchanges, remote meetings and visits to non-reporting FLHS. The case of HN 5, characterised by complete archiving, use of a dashboard and systematic follow-up of recommendations in executive committee meetings, suggests without establishing causality that formalising such routines could reduce some constraints, although the pattern may also reflect greater supervision or resources. The Mumbunda Health District therefore illustrates a decoupling between information, decision-making and implementation: FLHS deliver services, while strategic tools remain concentrated at the main FLHS and DHMT. This interpretation is consistent with Brinkerhoff et al. (2019) and Kamadjeu et al. (2024) and supports institutionalising shared microplanning, local data analysis and accountable supervision (48, 49).

Financing had a median score of 21% (IQR: 7–36%), with a major bottleneck profile in 82.8% of FLHS. The interviews support the concept of an 'underfunded peripheral operational capacity', reflecting the gap between planned activities and the resources actually available to HAs and FLHS. Participants made this

gap tangible: in some HAs, no operational budget line was perceived, whereas elsewhere the budget appeared in the microplan but funds remained at HD level. HNs therefore financed transport, vaccine collection, communication or supervision from their own resources. These accounts help explain why the financing bottleneck affected both main and satellite FLHS, which shared dependence on funds managed upstream. The contrast between funded campaigns and unsupported routine activities further illustrates the disconnect between planning, disbursement and implementation. This finding is consistent with Adjagba et al. (2024) in Kenya and Kamya et al. (2021) in Uganda, where low allocations, disbursement delays and dependence on partners constrain peripheral activities (9–11, 50). Those studies examined financing bottlenecks using different conceptual and health-system levels from the present study. In Mumbunda, the findings point to an operational EPI constrained by underfunding: responsibilities are delegated to peripheral actors while financial authority remains centralised. Using revenue from weighing to support vaccination illustrates cross-subsidisation that could weaken operational free access, without demonstrating systematic charging for vaccination. As reported by Ozawa et al. (2016) and Sriudomporn et al. (2023), funding gaps often concern service-delivery costs rather than vaccine procurement alone (51, 52). The interviews therefore document limited peripheral access to operational resources rather than an absolute absence of funding, supporting the need for predictable and traceable financing at implementation level.

Resource generation had a median score of 58.3% (IQR: 45.8–67.7%). The interviews suggest that this heterogeneity reflected differences in logistical capacity and concentration of vaccination expertise among a limited number of staff. Nominal availability of resources did not guarantee functionality. Some HAs stored vaccines in non-approved refrigerators without temperature monitoring or relied on neighbouring HAs, whereas HN 4 described an approved refrigerator supported by a dedicated solar system. These findings are consistent with Yawson et al. (2017), Siddiqi et al. (2022) and Sinnei et al. (2023), who link cold-chain reliability to equipment, temperature monitoring and contingency arrangements (8, 53, 54). Human-resource vulnerability followed a similar pattern: absence of key staff could interrupt vaccination, while training was outdated or limited to briefings. Sheffel et al. (2024) show that such challenges relate not only to staffing levels but also to distribution, knowledge and supervision (55). In the Mumbunda Health District, logistical and human-resource weaknesses therefore created a peripheral productive capacity with critical dependencies on neighbouring services, equipment or key personnel. The challenge lies not only in the availability of resources but also in their functionality, distribution and continuity.

Service delivery had the least unfavourable profile, with a median score of 72.7%. Services were therefore being maintained, although this score did not guarantee that every child was reached. The interviews showed that the relatively favourable score coexisted with precarious dependence on community actors and fragile accessibility and acceptability. Community health workers and community organisations raised awareness, contacted mothers and identified zero-dose and under-vaccinated children, but their contribution depended on voluntary work and limited support. Bakkabulindi et al. (2023) and Raven et al. (2020) show that community health-worker contributions are more sustainable when roles, tools, training and supervision are institutionalised (6, 8, 56, 57). In FLHS without local vaccine storage, some children identified during consultations had to return on scheduled vaccination days, creating missed opportunities, a mechanism also reported elsewhere (6, 58). Peripheral costs, scheduling conflicts, rainfall, residential mobility, language barriers and rumours further complicated access. Limited availability of AEFI forms and irregular notification represented an additional weakness not fully captured by the overall score (59). Together, these findings reflect a fragile conversion of service availability into actual vaccination and support measures to reduce postponement, verify vaccination status at each contact and strengthen institutional support for community health workers.

Taken together, the findings help illuminate the coexistence of reported administrative coverage of 111% (17) with weak peripheral operational capacities. Informational fragility limits understanding of the target population and ownership of microplanning, potentially compromising resource allocation. Insufficient and centralised financing can in turn reinforce logistical dependencies, contribute to irregular vaccination sessions and increase missed opportunities for vaccination. The four functions therefore do not generate isolated bottlenecks; rather, they form an interconnected chain linking information, planning, resources and service delivery. In this context, administrative coverage calculated from reported doses and estimated target populations may remain high without demonstrating schedule completion, territorial equity or effective reach to every child. The reported 111% should therefore be interpreted as an administrative coverage estimate rather than as direct evidence of population-level coverage.

Following Meadows' systems-thinking logic and considering the observed findings, stewardship and financing constitute two priority levers for strengthening the EPI in the Mumbunda Health District (60, 61). In the context of health-system homeostasis (60, 62), the six conditions for systems change proposed by Kania et al. (2018), organised across structural, relational and transformative dimensions, provide a relevant interpretive framework (63). At the structural level, strengthening the EPI requires policies that clarify responsibilities, institutionalise the participation of satellite FLHS in microplanning, and ensure dedicated, predictable and equitable financing. Practice changes should strengthen local use of data, monitoring, formative supervision and budget tracking.

At the relational level, regular consultation among the DHMT, FLHS, community actors and partners should strengthen connections and rebalance decision-making power towards satellite FLHS. At the transformative level, mental models should evolve towards routine use of data for decision-making, a broader understanding of operational free care, and shared territorial responsibility. These orientations, derived from the observed bottlenecks, still require prioritisation, co-development and evaluation with local stakeholders.

This study has several methodological strengths. First, the sequential explanatory mixed-methods design enabled integration of quantitative and qualitative findings to describe EPI bottlenecks and explore their underlying causes (64). Second, triangulation across document review, observation, quantitative data and interviews strengthened the credibility of the findings. Full reading and systematic analysis of the transcripts also enabled in-depth exploration of the qualitative material. Third, the cross-sectional design was appropriate for exploring, describing and explaining bottlenecks at a defined period (29). Fourth, the study's originality lies in its systemic analysis of the different functions of a local immunisation system across the HAs of an urban Health District characterised by peri-urban dynamics, high population mobility and a plurality of providers.

The study also has limitations. First, its cross-sectional design allows bottlenecks to be identified and explored but does not allow their evolution over time to be tracked or the temporality and causality of observed relationships to be established definitively (29). Second, the qualitative component did not directly explore the perspectives of the DHMT, other service providers, community actors, partners or parents. Nevertheless, the diversity of participants and FLHS profiles enabled several organisational configurations of the EPI to be documented. Third, because the findings derive from a single Health District, they

cannot be statistically generalised to all Health Districts in Haut-Katanga Province or the DRC. They may, however, contribute to analytical or theoretical generalisation and may be transferable to Health Districts with characteristics similar to Mumbunda (29, 65). Finally, aggregating indicators into scores, medians and bottleneck categories facilitated synthesis but may have attenuated differences between FLHS and simplified complex organisational realities.

Conclusion

This study reports that stewardship/piloting was the most severe bottleneck (median: 8.33%), followed by funding (21%). Qualitative data link this configuration to informational and territorial fragility, weak ownership of peripheral planning, non-institutionalized adaptive governance, and underfunded operational capacity. Interacting with logistical vulnerabilities, the concentration of vaccination expertise, precarious community participation, and access difficulties, these constraints demonstrate that the bottlenecks in the EPI are neither isolated nor solely attributable to a lack of resources. They also explain why an administrative coverage rate of 111% does not guarantee schedule completeness, territorial equity, or effective reach for every child.

Sustained improvements in vaccination coverage therefore require prioritizing the strengthening of local governance and funding, particularly through shared micro-planning with satellite health services, local use of reliable data, predictable operational resources, a functional cold chain, and institutionalized support for community actors. While the results are not statistically generalizable beyond Mumbunda, the observed decoupling between administrative performance and peripheral operational capacities may shed light on other local systems facing the same paradox. Future research should integrate the perspectives of families, community actors, the DHMT, provincial and national levels, and partners, and jointly examine administrative data and coverage figures from population-based surveys.

Abbreviations

DHO	District Health Office
DHMT	District Health Management Teams
FLHS	First-level health services
Main FLHS	Main first-level health service
Satellite FLH	Satellite first-level health service
SD	Standard deviation
IQR	Interquartile range
HA-NIC	Health Area Nurse-in-Charge
F-NIC	Facility Nurse-in-Charge
KR-20	Kuder–Richardson coefficient 20
AEFI	adverse events following immunization
WHO	World Health Organization
EPI	Expanded Immunization Program
QUAL	Qualitative component
QUAN	Quantitative component

Declarations

Ethical approval and consent to participate

In accordance with the institutional procedures in place at the School of Public Health of the University of Lubumbashi for specialization studies, this study was deemed exempt from review by a research ethics committee. The School of Public Health of the University of Lubumbashi instead authorized the study through a research permit, issued on November 3, 2025 [Appendix 4], to ensure the scientific and ethical compliance of the research protocol. Subsequently, the Mumbunda health district and the management of the FLHS were informed of the study's purpose and objectives, as well as the data collection methodology. Voluntary participation in the study is contingent upon obtaining informed consent from all participants.

In accordance with the ethical principles of the 1964 Declaration of Helsinki , the anonymity, beneficence, confidentiality, and dignity of the participants were guaranteed. Participants were informed of their right to freely consent or to withdraw from the study at any time. Appropriate data management was ensured in three stages: first, recordings, transcripts, and field notes were deleted from their original media. Second, they were saved in password-protected files on a computer and an external hard drive. Third, during transcription, the data were anonymized and/or pseudonymized and managed as such after the removal of all elements that could identify the participants. To guarantee the credibility and validity of this data, before anonymization, each participant had the right to review their responses/statements and was free to request their deletion (or not). Only previously anonymized/ pseudonymized data , stripped of information allowing direct identification of the participants, was used during the AI-assisted process. Before participating, each participant gave their informed consent and was informed of the questionnaire's content. Participant data was anonymized and coded to ensure confidentiality.

Data availability

Anonymized quantitative data supporting the findings can be obtained from the corresponding author upon reasonable request and subject to applicable institutional conditions. Full qualitative transcripts are not publicly available due to the risk of re-identifying participants.

Consent to publication

Not applicable.

Conflicts of interest

The authors declare that they have no conflict of interest.

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Author contributions

CKD: Conceptualization, curation, data analysis, research, methodologies, project administration, supervision, resources, work visualization, drafting and revised version, and validation of the final manuscript. **DCK:**Conceptualization, methodologies, project administration, supervision, resources, work visualization, drafting of the initial and revised versions, and validation of the final manuscript. All authors have read and approved the final manuscript. **ASS:** Project administration, data collection, resources, methodologies, work visualization. **PPM**: Project administration, data collection, supervision, methodologies, work visualization, and final version validation. **IKO:**Project administration, data collection, supervision, methodologies, work visualization, and final version validation. **AMN:**Conceptualization, methodologies, project administration, supervision, resources, work visualization, drafting and revision of the manuscript, and validation of the final version. All authors have read and approved the final version of the manuscript.

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Figures

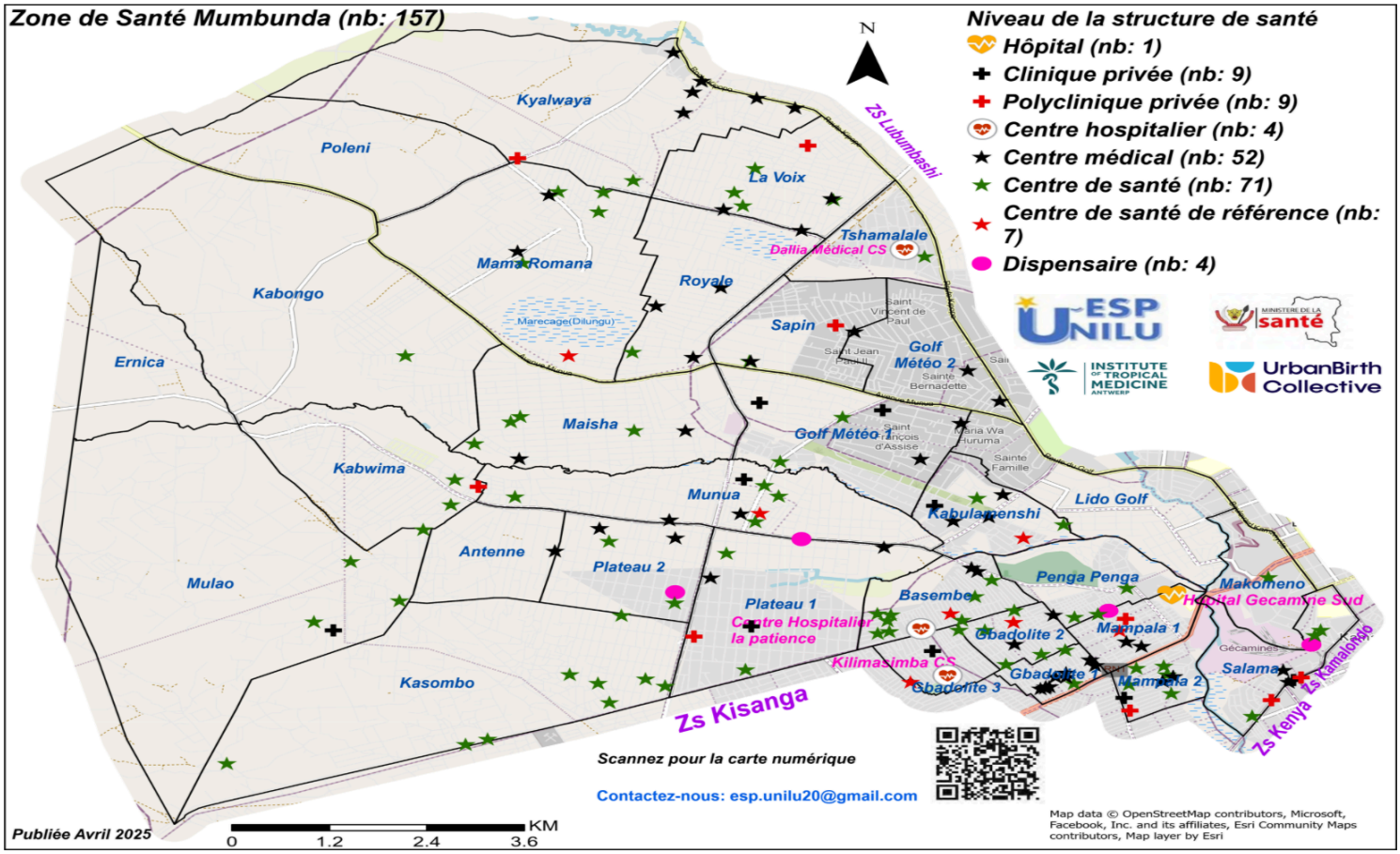


Figure 1

Mapping of the Mumbunda health district (32)

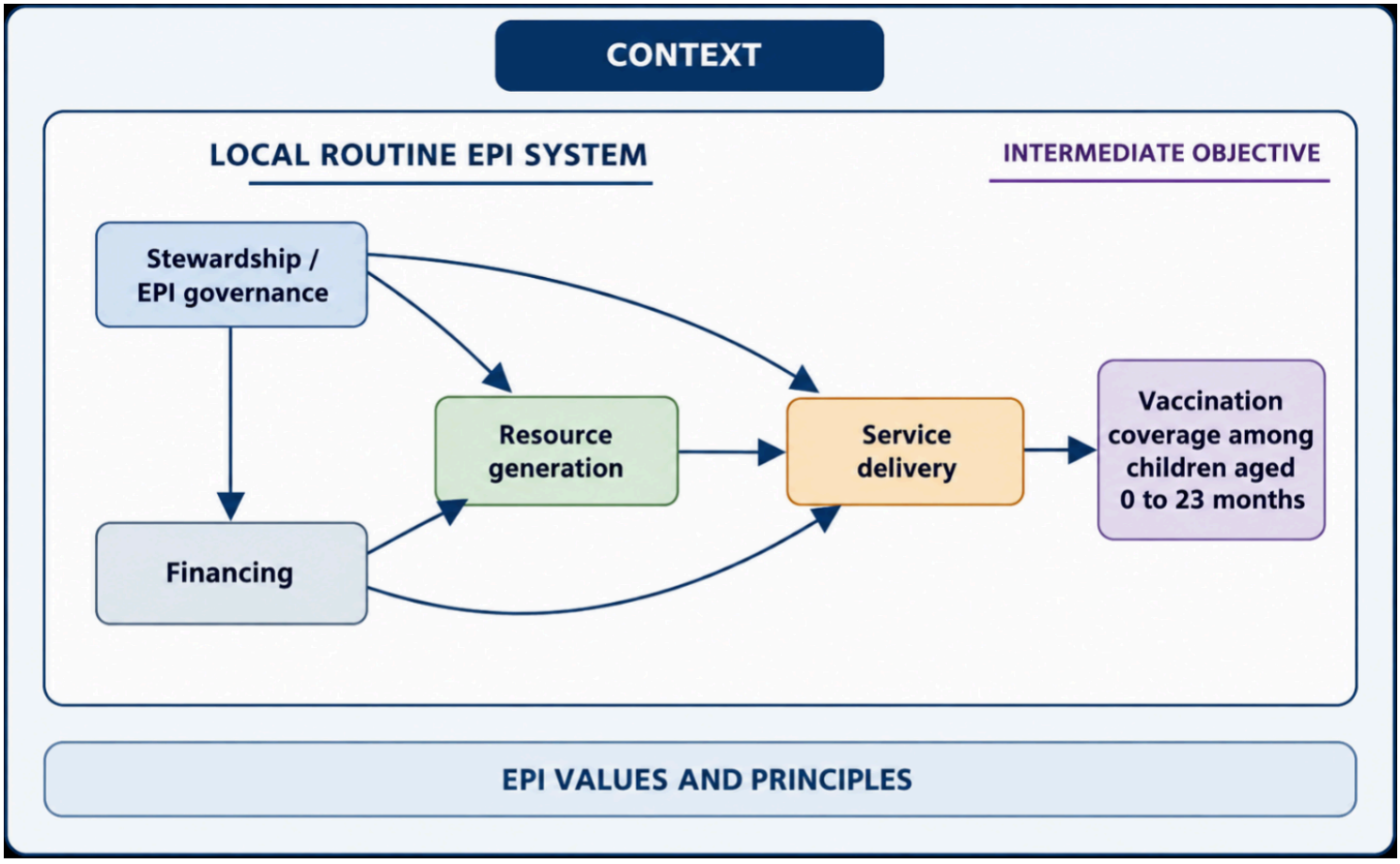


Figure 2

Conceptual model of bottlenecks in routine EPI immunization coverage among children aged 0–23 months , adapted from the WHO four-function model of the health system (18) **and the health systems dynamics framework of Van Olmen et al, 2010** (20) **. Source:** Author's design and graphic formatting assisted by ChatGPT (OpenAI , GPT -5.6), August 2026 **.**

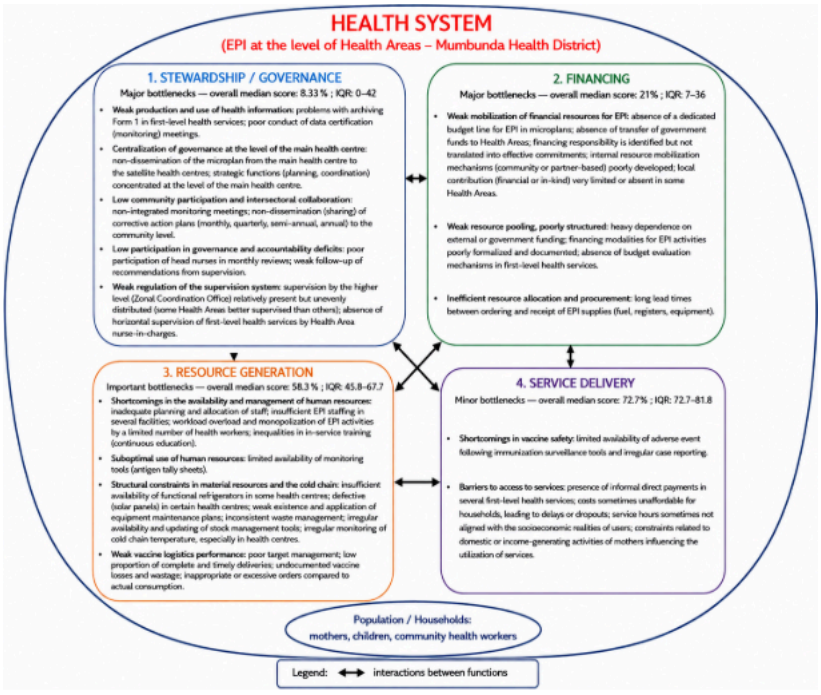


Figure 3

Illustration of the bottlenecks in the four functions of the EPI at the health sector level, in the Mumbunda health district

The bottlenecks in the EPI service delivery function are minor [(The overall median score for this function is 72.7% (72.7-81.8)], but nevertheless present some constraints: (i) weaknesses in vaccine safety, particularly limited availability of adverse events following immunisation (AEFI) forms and irregular case notification; and (ii) barriers to access, including informal direct payments in several FLHS, costs perceived by some households as unaffordable and leading to postponement or discontinuation of visits, opening hours that were sometimes poorly aligned with users' socioeconomic circumstances, and constraints related to mothers' domestic or economic activities (Tables 3, Box 1 and Figure 3).

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