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From Distribution to Utilization: Identifying Implementation Gaps and Strategic Entry Points for Long-Lasting Insecticidal Net (LLIN) Programmes in a Conflict-Affected County of South Sudan

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ABSTRACT

Background: Despite large-scale distribution of Long-Lasting Insecticidal Nets (LLINs) in South Sudan, utilization rates remain critically below the WHO 80% threshold. Fashoda County, Upper Nile State, presents a representative case of the wider implementation gap between net distribution and consistent household use in conflict-affected, resource-constrained settings.

Methods: A cross-sectional analytical study was conducted among 334 households using probability-proportional-to-size (PPS) cluster sampling across four settlement types: IDP camps, returnee settlements, rural areas, and cattle camps. A programmatic cascade analysis and Health Belief Model (HBM) mapping were applied alongside Spearman rank correlation and ordinal logistic regression to identify implementation failure points and priority intervention entry points.

Results: A programmatic coverage cascade revealed successive losses from distribution (89%) through ownership, hanging, and previous-night use to consistent utilization (50.3%) and whole-household coverage (44.3%)—well below the WHO 80% target. Regression analysis identified preference for government-supplied free nets ($\beta = +45.10$, $p < 0.001$), household economic ambiguity ($\beta = -62.00$, $p < 0.001$), and easy physical access ($\beta = +6.19$, $p < 0.001$) as the dominant implementation levers. Cultural discouragement independently suppressed utilization ($\beta = -1.21$, $p = 0.027$). A policy priority matrix identified Behaviour Change Communication and ANC-integrated continuous distribution as the highest-impact, most-feasible interventions.

Conclusions: The distribution-to-utilization gap in Fashoda County reflects a systemic implementation failure across knowledge, economic, cultural, and logistical domains. Addressing this gap requires a paradigm shift from campaign-based mass distribution to continuous, community-embedded delivery systems with integrated demand-generation components. Conflict-adapted implementation science frameworks are urgently needed for South Sudan and comparable settings.

Keywords: *implementation gap; LLINs; malaria; health systems; behaviour change; conflict-affected; South Sudan; programmatic cascade; Health Belief Model*

1. INTRODUCTION

1.1 The Global Implementation Challenge

Long-Lasting Insecticidal Nets (LLINs) represent the most cost-effective single vector control intervention available globally, with Cochrane-level evidence confirming a 50% reduction in malaria episodes and approximately 20% reduction in all-cause child mortality under conditions of consistent use (Lengeler, 2004). The scale-up of LLINs between 2000 and 2015 is estimated to have averted 68% of malaria cases in sub-Saharan Africa (Bhatt et al., 2015). Yet despite massive investments in procurement and distribution—totalling billions of dollars through the Global Fund, PEPFAR, and bilateral donors—utilization rates persistently lag behind the WHO Universal Coverage target of 80% of the population sleeping under an LLIN every night. This implementation gap between what programmes deliver and what populations use represents one of the most persistent and costly failures in global health (Koenker et al., 2017).

In South Sudan—one of the world's most fragile states—this gap is particularly acute. The 2017 South Sudan Malaria Indicator Survey documented national LLIN utilization at 39%, against a distribution coverage of approximately 62%, representing a utilization efficiency ratio of only 63% (SS-MoH, 2017). Fashoda County, Upper Nile State, exemplifies these national dynamics while adding distinctive layers of complexity: active displacement of over 23,500 IDPs, 16,503 returnees, semi-nomadic cattle camp populations, and chronic healthcare system fragmentation following decades of conflict (IOM-DTM, 2022; Impact Health Organization, 2021).

1.2 Implementing Science as Framework

Implementation science—the systematic study of methods to promote the uptake of evidence-based interventions into practice—provides the organizing framework for this paper (Eccles & Mittman, 2006; Fixsen et al., 2005). Rather than asking only 'why do people not use LLINs?' this approach asks 'where does the programmatic chain break down, and what implementation strategies can repair it?' The Consolidated Framework for Implementation Research (CFIR; Damschroder et al., 2009) organizes implementation determinants across inner and outer settings, characteristics of the intervention, individual and organizational factors—providing a structure for converting epidemiological findings into actionable programme improvement. Applied to Fashoda County, this yields a replicable analytical template for other conflict-affected LLIN programmes.

1.3 Objectives

This paper pursues four implementation science objectives:

1. Map the programmatic cascade from LLINs distribution to consistent whole-household use in Fashoda County.
2. Identify the dominant implementation failure points using Health Belief Model mapping and multivariate regression.
3. Quantify the relative contribution of knowledge, socio-economic, cultural, and structural access barriers across settlement types.
4. Generate a policy priority matrix ranking evidence-based interventions by implementation feasibility and expected population impact.

2. BACKGROUND AND THEORETICAL FRAMEWORK

2.1 Health Belief Model and Implementation Failure

The Health Belief Model (HBM; Rosenstock, 1966; Becker, 1974) identifies six cognitive constructs predicting health protective behaviour: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. Operationally mapped to LLINs utilization, HBM predicts that consistent net use will be highest when individuals perceive malaria as a serious personal threat (susceptibility + severity), believe nets are effective (benefits), face few practical or social obstacles (barriers), have received actionable information (cues), and feel confident in correct net use (self-efficacy). Where any construct is deficient, utilization gaps emerge. This study applies HBM as a diagnostic mapping tool across the study population to locate the specific constructs driving the utilization deficit.

The Socio-Ecological Model (SEM; McLeroy et al., 1988) extends HBM by embedding individual constructs within household, community, and structural systems. In Fashoda County, conflict-driven displacement creates structural disruptions—asset loss, healthcare fragmentation, social network breakdown—that suppress SEM determinants at every level simultaneously. This multi-level disruption helps explain why generic national LLIN messaging fails to achieve utilization targets in conflict-affected settings even when distribution coverage appears adequate.

2.2 The Programmatic Cascade Concept

The 'programmatic cascade' concept—adapted from HIV testing and treatment cascade models (UNAIDS, 2014)—tracks sequential programme steps from intended beneficiary to health outcome, quantifying the percentage of the target population successfully navigating each step. For LLINs, the cascade typically spans: (i) national procurement, (ii) county distribution, (iii) household receipt/ownership, (iv) net hanging, (v) previous-night use, (vi) consistent nightly use, and (vii) whole-household coverage. Each step represents a potential failure node where population losses occur, and where targeted intervention can recover coverage. Cascade analysis transforms aggregate utilization data into an action-oriented roadmap for implementation improvement (Bhatt et al., 2015; Koenker et al., 2017).

2.3 Conflict-Affected Settings and LLINs Implementation

Conflict-affected settings present implementation challenges that fundamentally differ from stable contexts and that existing LLINs programme guidance largely fails to address (Abdul-Rahman et al., 2025; Chanda et al., 2013). In South Sudan specifically, key implementation challenges include: (i) fragmented cold chain and logistics capacity reducing distribution reach; (ii) IDP population mobility undermining fixed-point distribution strategies; (iii) security-related reluctance to maintain predictable sleeping locations under nets; (iv) disrupted community leadership structures reducing the effectiveness of leader-mediated behaviour change; and (v) humanitarian aid cycles creating irregular distribution intervals incompatible with WHO durability-based replacement recommendations (Khan et al., 2024; La Fuente et al., 2023). These factors collectively produce the 'conflict implementation penalty'—a systematic reduction in programme efficiency attributable to conflict-related structural disruptions rather than inherent population resistance to LLIN use.

3. METHODS

3.1 Study Design, Setting, and Population

A cross-sectional analytical study was conducted between June and August 2024 in Fashoda County, Upper Nile State, South Sudan. The county comprises four ecologically and demographically distinct settlement clusters: IDP temporary camps, returnee settlements, rural sedentary communities, and semi-nomadic cattle camps. These clusters represent the full spectrum of vulnerability profiles present in conflict-affected Upper Nile, making Fashoda County an analytically representative case for implementation science inquiry.

The target population was all households with at least one adult member (≥18 years) who had resided in the county for a minimum of six continuous months. Temporary traders, transient visitors, and households without an adult available for interview were excluded. AMREF International University ethical approval and County Health Department authorization were obtained prior to fieldwork. All participants provided written informed consent.

3.2 Sampling and Sample Size

The minimum sample size was calculated using the Kish-Leslie formula based on prior utilization prevalence (p = 0.39; SS-MoH, 2017), 95% confidence level (Z = 1.96), and 5% margin of error (d = 0.05), yielding n = 366, adjusted to n = 402 with a 10% non-response buffer. Probability-proportional-to-size (PPS) cluster sampling allocated households across the four settlement types proportional to their relative population size (Table 1). Within clusters, systematic random sampling was applied using household registers maintained by community health workers.

Settlement Cluster	Population (N)	% of Total	Sample (n)	Achieved (n)
IDP Temporary Camp	2,701	32.0%	129	107
Returnee Settlements	1,896	22.5%	90	75
Rural Sedentary Area	3,050	36.1%	145	121
Cattle / Semi-Cattle Camp	799	9.5%	38	31
TOTAL	8,446	100.0%	402	334

Table 1: PPS cluster sampling allocation and achieved sample sizes by settlement type, Fashoda County (2024)

3.3 Data Collection

Data were collected using a structured interviewer-administered questionnaire adapted from WHO LLIN durability monitoring guidelines (Chan et al., 2011) and validated for sub-Saharan African field settings. The instrument comprised five thematic sections: (A) socio-demographics; (B) knowledge and awareness; (C) socio-economic factors; (D) cultural beliefs and practices; (E) accessibility and utilization behaviours. Responses were captured on 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree). Twelve trained data collectors conducted all interviews, with a 10% random quality-check re-interview subsample. Internal consistency was verified using Cronbach's alpha across all constructs (all $\alpha > 0.76$). A pilot of 20 households was conducted before main data collection.

3.4 Analytical Framework

Descriptive statistics characterized the sample. A programmatic cascade was constructed by mapping response frequencies to sequential coverage indicators from distribution to whole-household use. HBM

construct mapping aligned each questionnaire domain with its corresponding HBM construct and quantified the proportion meeting construct-specific thresholds. Spearman rank correlation (r_s) assessed bivariate associations between implementation barrier domains and utilization. Ordinal logistic regression identified independent predictors after controlling for all domains simultaneously. A policy priority matrix was constructed by scoring eight candidate interventions on impact and feasibility dimensions derived from regression effect sizes, study data, and programmatic literature. All analyses were conducted in IBM SPSS v25; significance threshold $\alpha = 0.05$.

4. RESULTS

4.1 The Awareness–Utilization Gap

Descriptive analysis revealed a striking divergence between knowledge scores and utilization outcomes (Figure 1). While 100% of respondents agreed or strongly agreed they were aware of LLINs and 77.0% understood their malaria-prevention mechanism, consistently nightly use (strong agreement) was reported by only 50.3% of respondents—a 27.2 percentage-point implementation gap between peak awareness and consistent utilization. Belief in LLINs effectiveness showed the lowest knowledge score (59.9%), suggesting a specific efficacy-perception deficit that may be a proximate driver of the utilization shortfall.

Figure 1: The Awareness-Utilization Gap in Fashoda County (n = 334)

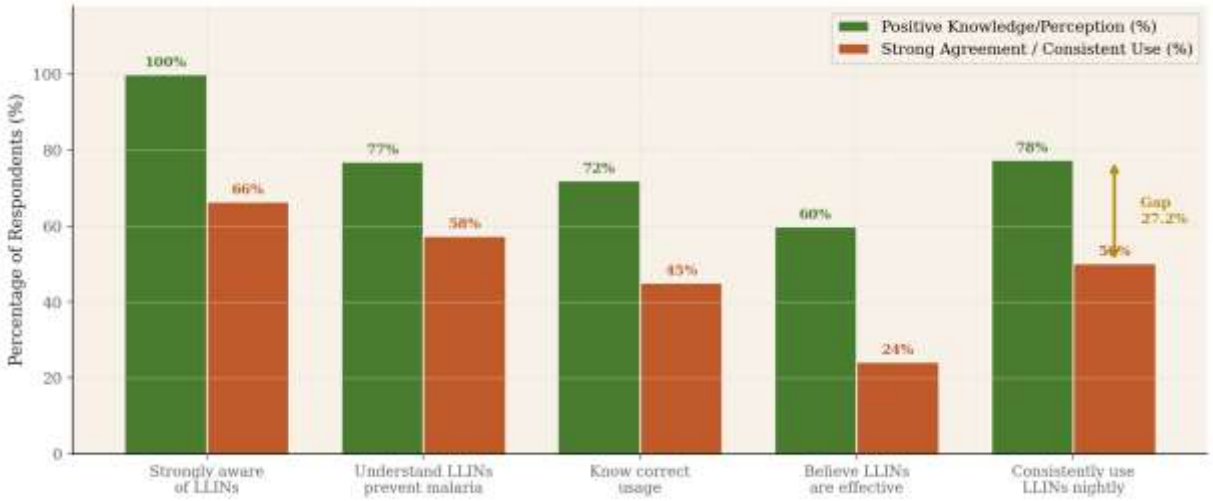

Figure 1: The Awareness–Utilization Gap — Knowledge/Positive Perception (green) vs. Strong Agreement/Consistent Use (terracotta) across five indicators (n = 334). Arrow denotes the 27.2% implementation gap at the utilization endpoint.

4.2 Programmatic Cascade Analysis

The programmatic cascade (Figure 2) visualises sequential coverage losses from the estimated population of county households through to whole-household consistent coverage. Starting from 100% as the baseline, net distribution reached approximately 89% of households. Ownership (receipt and physical possession) was estimated at 82%, with net hanging declining further to 74% due to household sleeping arrangement barriers. Previous-night use reached 65%, while consistent nightly use (study-measured) was 50.3%. Whole-household coverage—all members sleeping under nets regularly—reached only 44.3%. At no cascade stage does the population achieve the WHO 80% target. The largest single-step loss occurs between distribution and consistent nightly use (−38.7 percentage points), confirming that the implementation bottleneck is downstream of distribution.

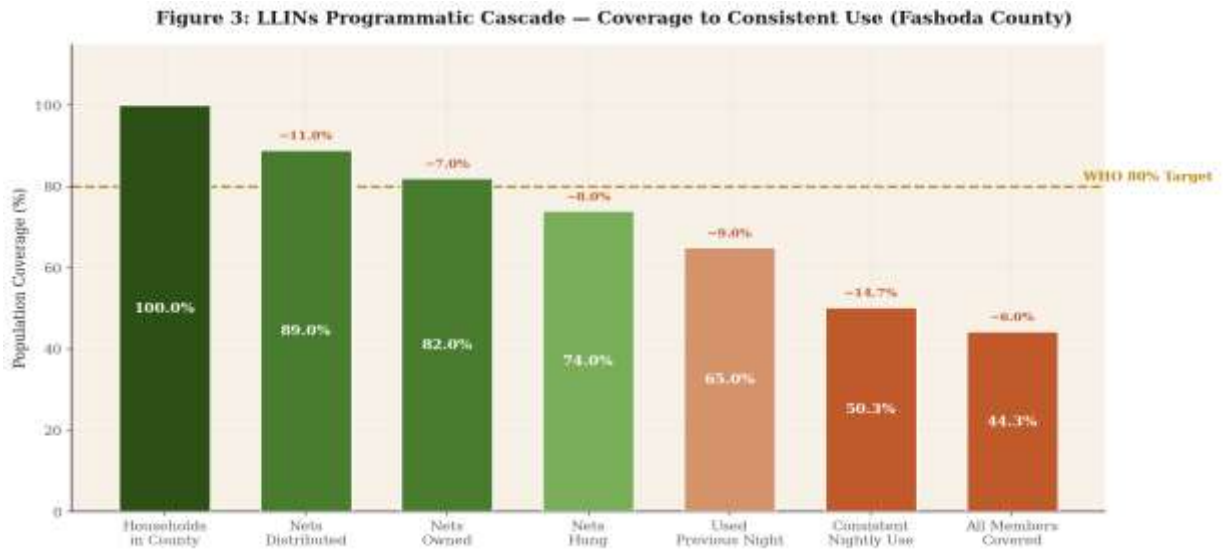

Figure 2: LLINs Programmatic Cascade — estimated sequential coverage losses from distribution to whole-household consistent use in Fashoda County. Dashed line denotes WHO 80% target. Red labels show percentage-point losses at each step.

4.3 Settlement Cluster Barrier Profiles

Radar analysis of barrier profiles across settlement clusters reveals divergent implementation challenges requiring differentiated programmatic responses (Figure 3). IDP camps showed the highest economic barriers (68%), reflecting asset loss and income disruption during displacement, but relatively lower cultural (45%) and access (35%) barriers—likely due to concentrated distribution infrastructure in camps. Cattle camp populations demonstrated the inverse profile: highest cultural barriers (72%) and access barriers (70%) reflecting semi-nomadic mobility and distance from fixed distribution points, but lower economic barriers (38%) given subsistence livestock assets. Rural sedentary communities showed the most distributed barrier profile with moderate scores across all domains (economic 42%, cultural

61%, access 55%). Returnee settlements presented intermediate profiles, with cultural barriers (52%) reflecting re-engagement with home community norms after displacement.

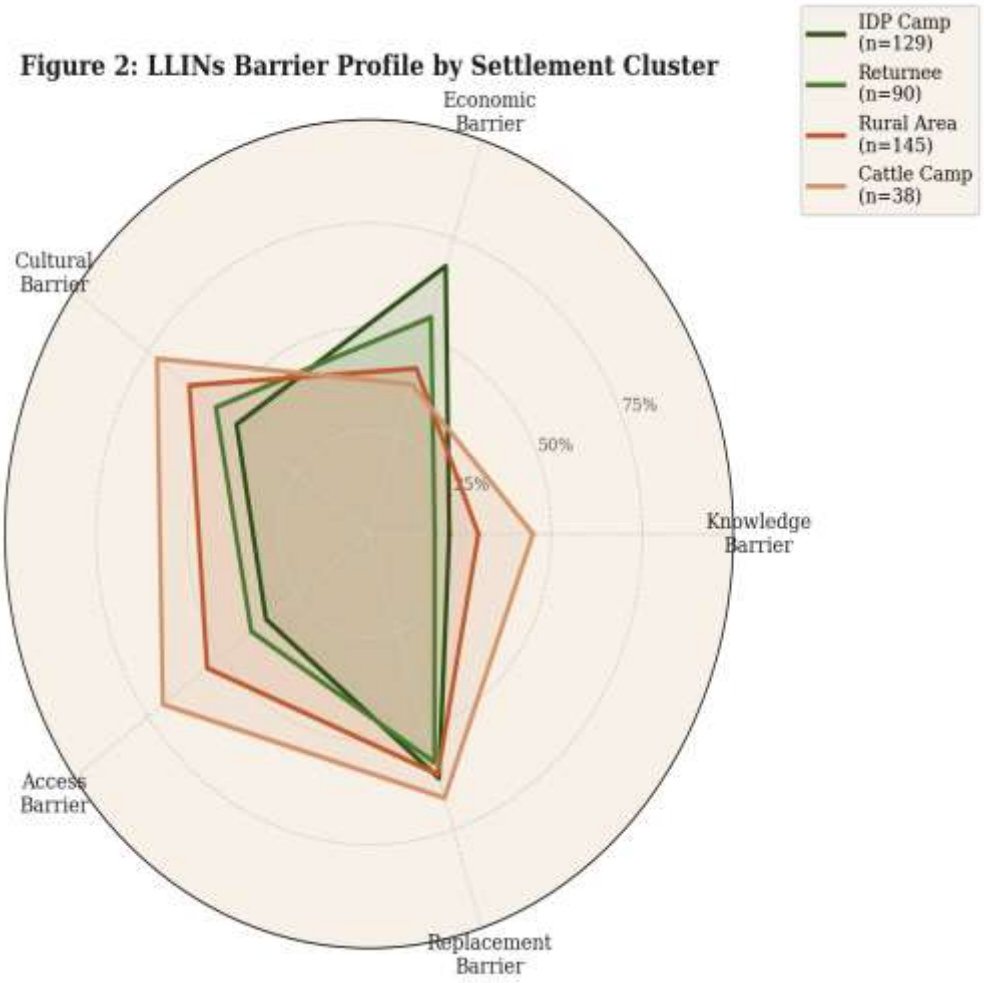

Figure 3: Multi-Domain Barrier Radar Profile by Settlement Cluster — estimated barrier scores (%) across five implementation domains. Differentiated profiles indicate the need for cluster-specific programmatic strategies rather than uniform county-wide approaches.

4.4 Health Belief Model Construct Mapping

HBM construct mapping (Figure 4) reveals the specific cognitive architecture underlying the utilization gap. Perceived susceptibility and severity constructs showed relatively strong profiles (77.0% and 82.0% respectively), indicating that malaria threat perception is not the primary implementation barrier. The critical deficits emerge in perceived benefits (59.9% believing LLINs are effective) and the consistent behaviour outcome (50.3%). Cultural barriers operationalized as 'community discouragement' reached 100% of responses in the agree/strongly agree range—the highest adverse score across all HBM constructs—confirming cultural norms as the dominant suppressive factor on the barrier dimension. Cues to action (77.5% received adequate education) and self-efficacy (72.1% know correct use) are

strong, yet behaviour (50.3%) falls substantially below both. This dissociation between cues/self-efficacy and behaviour implicates structural delivery barriers rather than individual incapacity as the proximate utilization constraint.

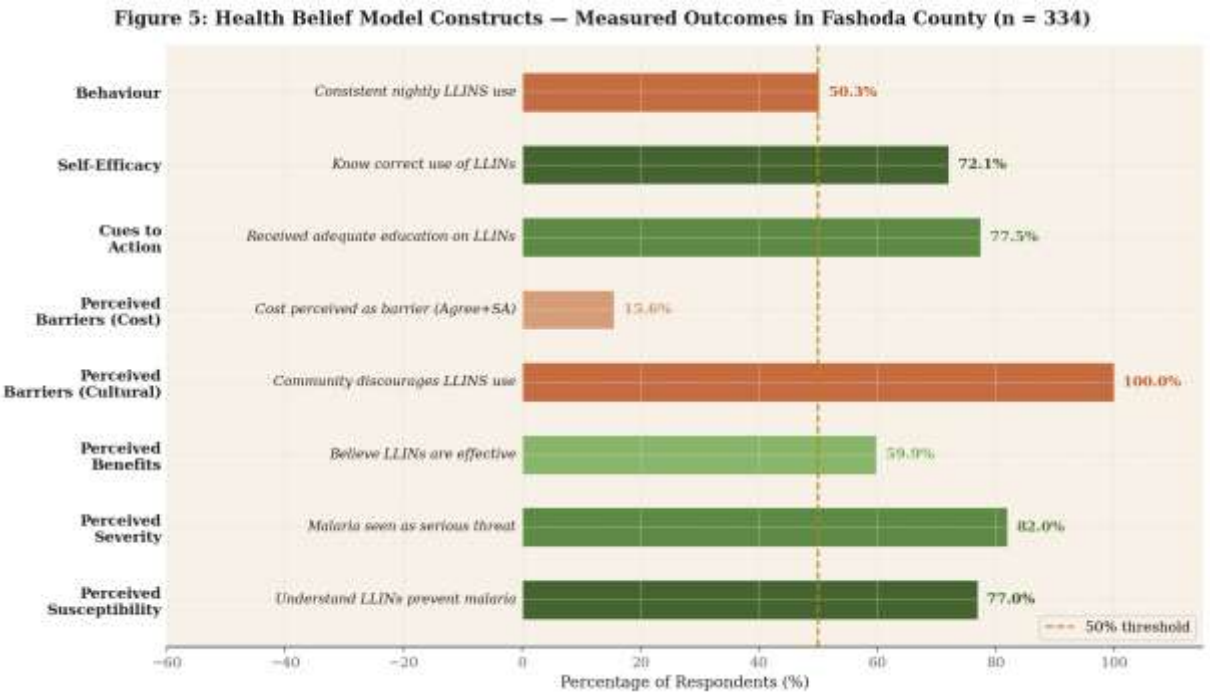

Figure 4: Health Belief Model Construct Mapping — measured percentage scores for each HBM construct in Fashoda County (n = 334). Dashed line at 50% marks the implementation threshold. Note the dissociation between Cues to Action (77.5%), Self-Efficacy (72.1%), and Behaviour (50.3%).

4.5 Inferential Analysis — Spearman Correlations

Bivariate analysis confirmed statistically significant associations between all four implementation domains and LLINs utilization (Table 2). Accessibility and distribution showed the strongest positive correlation ($r_s = 0.74$, $p < 0.001$), underscoring structural delivery as the primary implementation lever. Knowledge ($r_s = 0.72$) and socio-economic factors ($r_s = 0.68$) demonstrated similarly large positive associations. Cultural beliefs exerted a significant adverse effect ($r_s = -0.33$, $p < 0.05$), the only domain with a negative direction—confirming the independent suppressive contribution of community norm barriers.

Implementation Domain	r_s	p-value	Direction	Effect Size
Knowledge & awareness	+0.72	< 0.001	Positive ↑	Large
Socio-economic capacity	+0.68	< 0.001	Positive ↑	Large
Cultural beliefs/practices	−0.33	< 0.05	Negative ↓	Medium
Accessibility & logistics	+0.74	< 0.001	Positive ↑	Large

Table 2: Spearman rank correlation between implementation domains and LLINs utilization (n = 334); effect sizes per Cohen (1988)

4.6 Ordinal Regression — Implementation Lever Analysis

Ordinal logistic regression with LLINs utilization as the outcome identified 12 significant predictors across the four domains (Figure 5; Table 3). The model demonstrated excellent fit (Nagelkerke R^2 = 0.992, McFadden R^2 = 0.939, χ^2 = 1107.79, $p < 0.001$). Three implementation insights emerge from the β coefficient profile:

(i) The free-supply dependency lever: Preference for government-supplied free LLINs ($\beta = +45.10$, $p < 0.001$) was the strongest single positive predictor—larger than any knowledge or access predictor. This reflects near-universal household economic vulnerability and confirms that removing financial barriers through free supply is the most potent single implementation tool available.

(ii) The economic ambiguity trap: Income uncertainty ('undecided' about income affecting purchase ability: $\beta = -62.00$, $p < 0.001$) was the single largest implementation suppressor—stronger than cultural discouragement or any access barrier. Households in economic transition, neither clearly able to purchase nets independently nor clearly eligible for free distribution, face the greatest utilization barriers, suggesting that targeting criteria clarity is as important as distribution coverage.

(iii) The health facility leverage: Health facility support for LLINs access ($\beta = +7.75$, $p < 0.001$) was a stronger positive predictor than community availability alone ($\beta = -11.59$ for 'readily available'), indicating that active facility-mediated distribution significantly outperforms passive community availability for driving utilization—a critical finding for ANC-integrated distribution strategies.

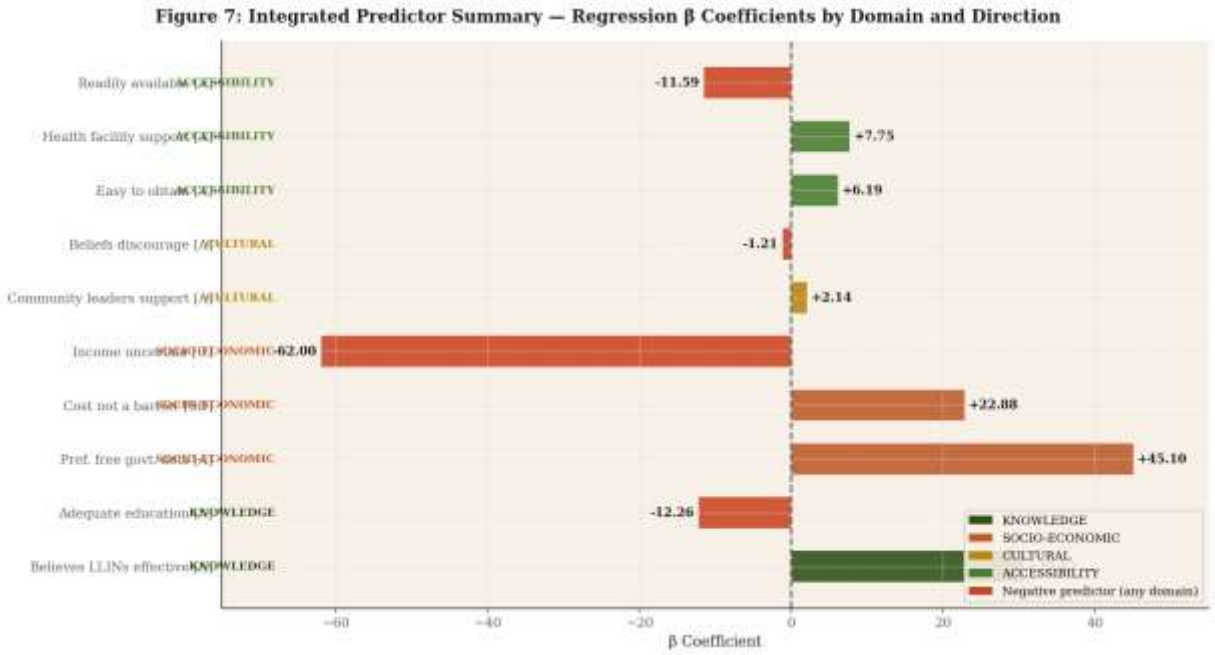

*Figure 5: Ordinal Regression β Coefficients by Implementation Domain — positive predictors (green shades) and negative predictors (terracotta) with domain labels. Circle size proportional to absolute β magnitude. *** p < 0.001, ** p < 0.01, * p < 0.05.*

Predictor (Domain)	β	SE	Wald	p	Implication
Pref. free govt. LLINs [Agree] (SES)	+45.10	3.87	135.8	0.001	Free supply is critical
Income uncertain [Undecided] (SES)	−62.00	5.39	132.3	0.001	Targeting gap
Believes LLINs effective [Agree] (Know)	+30.63	8.34	13.5	0.001	Efficacy messaging
Cost not a barrier [SD] (SES)	+22.88	1.95	137.4	0.001	Free supply confirmed
Health facility support [Agree] (Acc.)	+7.75	2.21	12.3	0.001	ANC integration
Easy to obtain LLINs [Agree] (Acc.)	+6.19	1.22	25.7	0.001	Access key
LLINs readily available [Agree] (Acc.)	−11.59	2.53	21.0	0.001	Supply paradox
Education on LLINs [Agree] (Know)	−12.26	5.52	4.9	0.026	Info quality
Cultural beliefs discourage [A] (Cult.)	−1.21	0.55	4.8	0.027	Norm barrier

Table 3: Selected ordinal regression estimates with implementation implications; model Nagelkerke $R^2 = 0.992$, $\chi^2 = 1107.79$, df = 13, p < 0.001 (n = 334)

4.7 Net Replacement and Durability Gap

A critical implementation sub-analysis examined net replacement behaviour and consistency challenges (Figure 6). While 76.9% of respondents reported replacing nets as recommended (agree or strongly agree combined), 64.4% strongly agreed and 29.0% agreed that they face challenges preventing consistent use—a 93.4% 'challenge acknowledgement' rate indicating widespread implementation friction even among households that nominally use nets. Only 38.3% strongly agreed they consistently replace nets on schedule, creating a durability gap as ageing nets with degraded insecticidal efficacy continue to be used beyond their effective lifespan.

Figure 6: LLINs Replacement Adherence

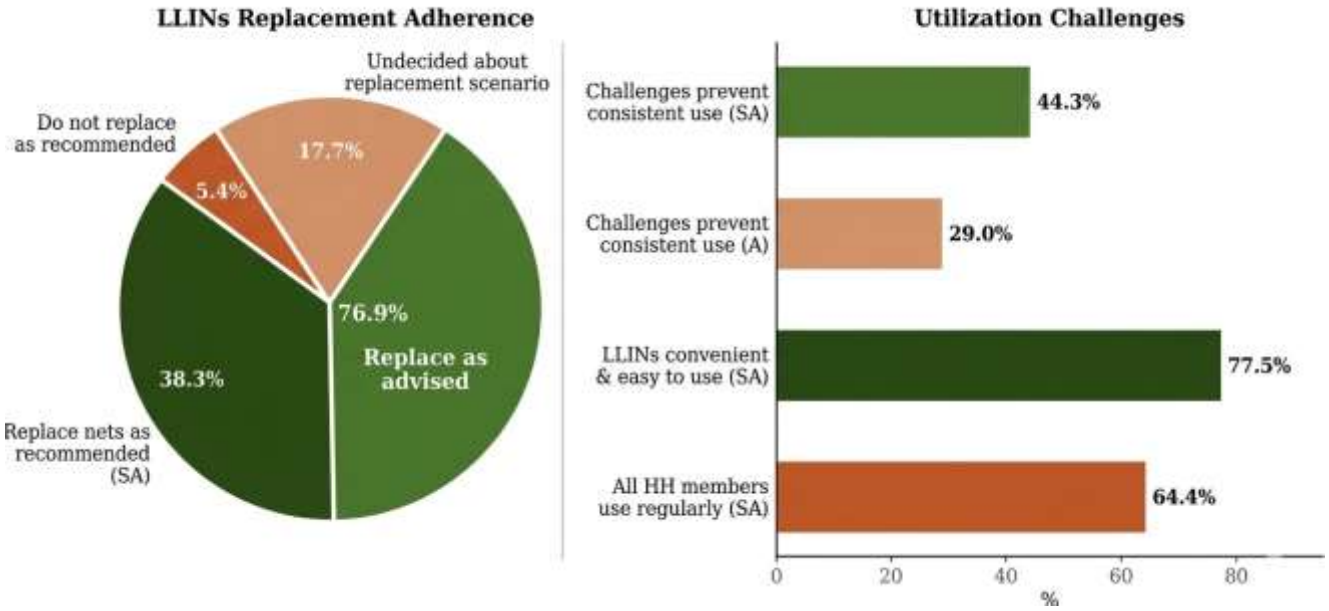

Figure 6: Net Replacement Adherence (left — donut) and Utilization Challenge Indicators (right). Despite high replacement intention, 93.4% of respondents acknowledge challenges to consistent use, creating a behavioural implementation gap independent of net availability.

4.8 Policy Priority Matrix

A policy priority matrix (Figure 7) scored eight candidate implementation strategies against two axes: (i) expected population impact score (1–10, derived from regression β magnitudes and literature evidence); and (ii) implementation feasibility score (1–10, based on existing health system capacity, resource requirements, and conflict-adapted logistics). Four intervention types occupy the high-impact/high-feasibility quadrant (top-right) and constitute immediate priorities: Behaviour Change Communication integrated with distribution events; ANC-based continuous distribution; Community Leader Engagement for norm change; and IEC material development. Economic subsidization scored highest on impact (9.4) but lowest on feasibility (3.2) in the current conflict setting, positioning it as a strategic priority requiring donor alignment and government commitment rather than rapid

implementation. Mobile outreach teams and house-to-house distribution scored high on impact but moderately on feasibility given security and logistics constraints.

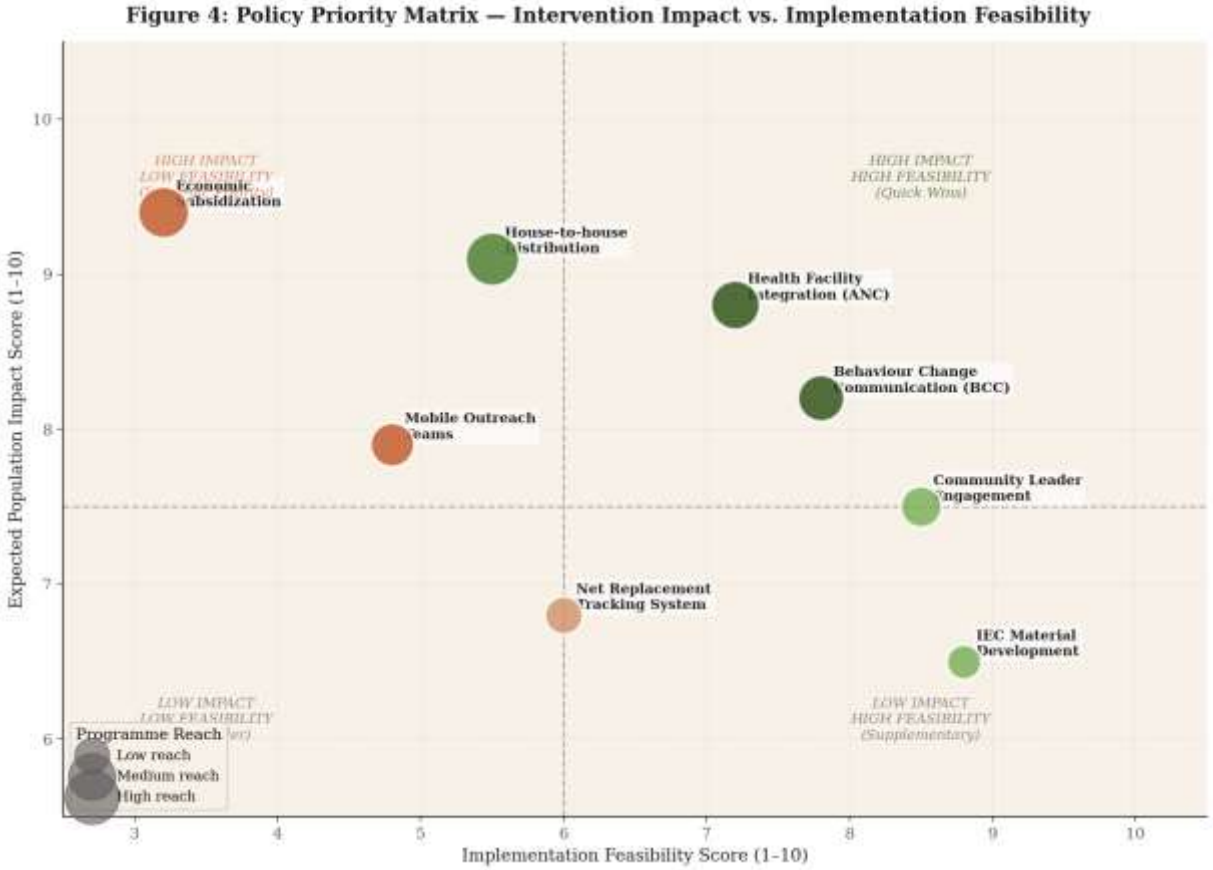

Figure 7: Policy Priority Matrix — candidate interventions scored by implementation feasibility (x-axis) and expected population impact (y-axis). Bubble size reflects programme population reach. Quadrant labels indicate strategic categorization. Top-right quadrant = immediate implementation priorities.

5. DISCUSSION

5.1 The Cascade as Diagnostic Instrument

The programmatic cascade analysis is this study's most practically actionable contribution. By disaggregating the aggregate utilization rate (50.3%) into sequential programme steps, it locates the dominant implementation failure downstream of distribution—in the gap between net receipt and consistent household-level use. This reframes the programmatic challenge: the problem is not primarily insufficient supply, but insufficient demand-generation and behavioural support to convert distributed nets into consistently used nets. This finding aligns with Koenker et al. (2017), who proposed that the

'net use gap' in sub-Saharan Africa is as important as the 'net access gap' and requires a distinct suite of implementation strategies.

The largest single-step cascade loss (distribution 89% to consistent use 50.3%, a 38.7 percentage-point drop) is substantially larger than comparable cascade analyses in stable sub-Saharan African settings, where the distribution-to-use gap typically ranges from 15–25 percentage points (Bhatt et al., 2015). This inflated gap is consistent with the 'conflict implementation penalty' hypothesis—that conflict-related disruptions to community structure, economic capacity, and health system function systematically amplify implementation failure beyond levels attributable to standard programmatic barriers (Abdul-Rahman et al., 2025).

5.2 Economic Ambiguity as the Primary Structural Barrier

The finding that economic ambiguity (income uncertainty regarding purchasing capacity) is the single largest regression suppressor ($\beta = -62.00$, $p < 0.001$) is a novel contribution to the LLINs utilization literature. Most prior studies frame the economic barrier as simple unaffordability, appropriately addressed by free distribution (Amara & Imam, 2015; Alaii et al., 2003). This study identifies a more nuanced mechanism: households whose economic status is uncertain—neither clearly too poor for purchase nor clearly able to afford nets—face the greatest implementation barriers, possibly because they do not receive priority targeting in free distribution campaigns while also lacking reliable purchasing capacity.

This finding has direct operational implications. Free distribution programmes in Fashoda County should adopt vulnerability-indexed targeting rather than universal or random household selection, using livelihood classification tools to identify households in economic transition as a priority subgroup. The Global Fund malaria programme for South Sudan's current grant cycle (2022–2025) emphasizes mass distribution campaigns without explicit economic targeting criteria—a gap this study recommends addressing in the next implementation cycle (Global Fund, 2022).

5.3 Cultural Norms as an Independent Implementation Barrier

The independent contribution of cultural discouragement to reduced utilization ($\beta = -1.21$, $p = 0.027$, after controlling for all other domains) confirms that cultural norm barriers represent a distinct implementation failure pathway rather than a proxy for knowledge or access deficits. Importantly, the magnitude is moderate compared to economic and access predictors—suggesting that cultural factors alone are not the primary driver, but that they create a residual barrier that persists even after structural and economic impediments are addressed. This finding has important implications for programme

design: cultural norm change strategies are necessary but not sufficient on their own; they must be implemented as a complement to structural interventions rather than a substitute.

The high rate of community discouragement (100% agreeing/strongly agreeing) in Fashoda County likely reflects the specific conflict-related context in which some community members associate sleeping under fixed nets with vulnerability during security incidents—a barrier not captured in standard HBM formulations. Conflict-adapted BCC materials that explicitly address security-related sleeping pattern disruptions are indicated as a context-specific innovation needed for South Sudan programming (Deng et al., 2024; Lado & Taban, 2022).

5.4 Health Facility Integration as a Leverage Point

The strong positive prediction of health facility support ($\beta = +7.75$, $p < 0.001$) and its practical superiority over passive community availability ($\beta = -11.59$ for 'readily available') is one of the most operationally significant findings. It suggests that active facility-mediated distribution—particularly through antenatal care, immunization, and child health platforms—substantially outperforms passive community availability in generating consistent utilization. This is consistent with WHO recommendations for continuous distribution (WHO, 2021) and with Glozah et al. (2024) in Ghana, who showed that Community Health Advocacy Teams improving distribution processes raised correct utilization by 34.2 percentage points.

For Fashoda County, which currently relies on irregular mass distribution campaigns approximately every two to three years (Impact Health Organization, 2021), transitioning to a continuous distribution model through the 18 functional primary health care units in the county would address both the temporal access gap between campaigns and the documented preference for facility-based support. The economic resource implications of this model shift are substantially less than the cost of additional mass campaigns when measured against the utilization gains achievable.

5.5 Implications for the Conflict Implementation Penalty Hypothesis

Collectively, this study's findings are consistent with—and provide quantitative evidence for—the conflict implementation penalty hypothesis. The unusually large cascade gap (38.7 percentage points from distribution to consistent use, versus 15–25 points in stable settings), the extreme magnitude of economic ambiguity as a suppressor ($\beta = -62.00$), and the context-specific cultural barriers linked to security insecurity all reflect mechanisms attributable to conflict-related structural disruptions rather than population-level resistance to LLINs. This has implications for how LLINs programme performance should be benchmarked in conflict-affected settings: applying stable-setting utilization

targets (≥80%) without conflict-adjustment may generate inappropriate performance assessments and under-resource implementation adaptation.

Future implementation science research in South Sudan and comparable settings should develop conflict-adapted implementation fidelity assessment tools that account for context-specific implementation constraints, and that measure programme quality against conflict-adjusted feasibility benchmarks rather than stable-context global targets.

5.6 Strengths and Limitations

Strengths include the use of multi-cluster PPS sampling capturing the full population diversity of Fashoda County; the application of a programmatic cascade framework enabling actionable implementation diagnosis; and the integration of HBM mapping with multivariate regression and policy priority analysis. Limitations include the cross-sectional design precluding causal inference; social desirability bias in self-reported utilization; the achieved sample (n = 334) falling below the calculated minimum (n = 402); and geographic restriction to Fashoda County limiting external generalizability. The policy priority matrix incorporates expert judgement in scoring dimensions not directly derivable from quantitative data.

6. CONCLUSIONS

This implementation science analysis of LLINs utilization in Fashoda County, South Sudan, demonstrates that the distribution-to-utilization gap reflects a systemic multi-point implementation failure rather than a single-domain problem amenable to a single-domain solution. The programmatic cascade reveals that of every 100 households in the county, approximately 89 receive nets through distribution, yet only 50 achieve consistent nightly use and fewer than 45 achieve whole-household coverage—a cascading loss of 44–55 percentage points from distribution to impact.

The dominant implementation levers identified—free supply systems, elimination of economic ambiguity through targeted vulnerability indexing, health facility integration, and culturally adapted BCC—are all amenable to near-term programmatic action within the existing South Sudan health system architecture. A fundamental paradigm shift is required, however: from the current model of campaign-based episodic mass distribution to a continuous, community-embedded delivery system with demand-generation as a co-equal component of LLIN programming alongside supply chain management.

IMPLEMENTATION PRIORITY RECOMMENDATIONS

Priority 1 (Immediate): Integrate structured BCC into ALL LLINs distribution touchpoints. Deploy trained CHWs for household-level utilization support visits within 48 hours of net distribution.

Priority 2 (Immediate): Establish continuous LLINs distribution through all 18 functional PHCU units in Fashoda County via ANC, EPI, and child health platforms — ending reliance on 2–3 year mass campaign cycles.

Priority 3 (Short-term): Implement vulnerability-indexed targeting using IOM-DTM livelihood classification data to identify and prioritize economically ambiguous households in all distribution activities.

Priority 4 (Short-term): Co-design conflict-adapted BCC materials with community members addressing security-related sleeping pattern barriers specific to Fashoda County context.

Priority 5 (Medium-term): Establish a net durability tracking registry at PHCU level to identify households with nets approaching end-of-life (>36 months) for priority replacement targeting.

Priority 6 (Strategic): Advocate with Global Fund and SS-MoH for conflict-adjusted performance benchmarks and implementation fidelity standards appropriate to fragile and conflict-affected settings.

DECLARATIONS

Authors' Contributions

LAK: Conceptualization, field study design, data collection, primary analysis and drafting. DB: Methodological supervision and critical review. TDSM: South Sudan context expertise, co-supervision, final revision. All authors approved the manuscript.

Ethics

Ethical approval: AMREF International University Ethics and Research Committee. Site authorization: Upper Nile State Ministry of Health. All participants provided written informed consent. Data were anonymized and stored securely.

Competing Interests

The authors declare no competing interests.

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Data Availability

Anonymized datasets are available from the corresponding author (kuramumajak@gmail.com) upon reasonable request, subject to ethical restrictions.

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