

Relationship of Logistics Management Information System Data Quality With Essential Medicine Stockouts in Malawi Using Spearman Rank Correlation Analysis

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Research Article

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Abstract

Background

Strengthening health research and information systems in low- and middle-income countries requires evidence on how data quality failures in routine health systems translate into poor health outcomes. In Malawi, stock-outs of essential medicines remain persistent despite the national rollout of the Open Logistics Management Information System (Open-LMIS). However, the statistical relationship between LMIS-derived performance indicators and stock-out burden has not previously been quantified at district level using real national LMIS data. This study examined the association between LMIS availability metrics, order fill rates, and essential medicine stock-out burden across government-managed health facilities at Blantyre District Health Office (DHO).

Methods

A cross-sectional study was conducted at six government-managed health facilities under Blantyre DHO. Nine essential medicines were extracted from the national Open-LMIS dataset for five months (January to June 2023; April was absent from the national LMIS data pull), generating 196 facility-product-month observation units. Spearman rank correlation analysis tested associations between mean facility-level availability percentage, order fill rate, accumulated stock-out days, and stock-out frequency. Bonferroni correction was applied for four simultaneous comparisons (adjusted $\alpha = 0.0125$). Descriptive Key Performance Indicator (KPI) analysis was structured around the Supply Chain Operations Reference (SCOR) model domains. The study is reported in accordance with the STROBE statement for cross-sectional studies.

Results

Madziabango Health Centre had the highest accumulated stock-out burden (269 days; 10 events; mean availability 69.1%), while Chilomoni Health Centre had zero stock-out days (mean availability 100.0%). Phenobarbitone 30mg had the highest accumulated stock-out days (251 days; 37.0% observation-level stock-out rate). Morphine sulphate had the highest observation-level stock-out rate (60.0%). Mean order fill rate across all facilities was 28.24%. Spearman rank correlation demonstrated strong, statistically significant negative associations between mean availability and both accumulated stock-out days ($r_s = -0.829$, $p = 0.042$) and stock-out frequency ($r_s = -0.829$, $p = 0.042$). Order fill rate was not significantly correlated with either stock-out outcome at facility level ($r_s = -0.257$ to -0.600 , $p = 0.208-0.623$).

Conclusions

Mean medicine availability recorded in Open-LMIS is a strong, statistically significant predictor of stock-out burden across government health facilities in Blantyre DHO. These findings validate LMIS data quality metrics as proxy indicators suitable for health system monitoring, early-warning system design, and policy prioritisation in LMIC public health supply chains. Investment in LMIS data quality and adherence is a high-priority, low-cost health system strengthening intervention with direct implications for medicine access and patient safety.

Background

Weak health information systems (HIS) are critical barriers to achieving health-related Sustainable Development Goals because health system performance cannot be adequately assessed or monitored where HIS data are incomplete, inaccurate, or untimely [10]. In public health supply chains, logistics management information systems (LMIS) represent the primary HIS infrastructure through which medicine demand data is collected, reported, and used for procurement and replenishment decisions. When LMIS data quality is poor, the entire supply chain planning cycle is compromised – from quantification and procurement through to district-level distribution and facility-level stock management [7].

In Malawi – a landlocked Sub-Saharan African country with a population of approximately 19 million and gross national income per capita of USD 620 – the healthcare system is heavily aid-dependent [13]. HIV/AIDS, tuberculosis, malaria, diarrhoeal diseases, and lower respiratory infections are the leading causes of morbidity and mortality, all requiring continuous and reliable essential medicine supply. Despite investment in Open-LMIS as a national logistics data platform and the formulation of the Health Products Management Strategy Master Supply Chain Transformation Plan (MSCTP) 2021–2026, stock-outs of essential medicines remain frequent, geographically distributed, and potentially predictable from routinely collected LMIS data [6].

The relationship between LMIS data quality and supply chain performance is well established internationally. Yadav identified ineffective supply chain information systems as the primary driver of medicine supply interruptions in LMICs [1]. USAID demonstrated that poor demand data produces inaccurate forecasts and stock-outs [2]. Chipeta et al. applied multilevel logistic regression to 940 Malawi health facilities and identified facility-level supply chain characteristics as significant predictors of consumable availability [3]. Mekonnen et al. demonstrated in Ethiopia that LMIS performance metrics are directly associated with essential medicine availability [4]. Evidence from Zambia showed that structured interventions to improve supply chain data use significantly reduced stock-out rates in public health facilities [11]. Strengthening data-informed decision-making at district level requires investment in HIS infrastructure and capacity building specifically for data use [10].

However, no study has applied Spearman rank correlation analysis to directly quantify the statistical association between LMIS-derived availability metrics and stock-out burden at district level in Malawi using real national LMIS data. Without this evidence, health system planners and policy-makers cannot

objectively quantify what improvement in LMIS data quality would yield in terms of reduced stock-out burden — and cannot prioritise LMIS data quality investment accordingly. This study addresses that evidence gap directly, providing the first statistically grounded assessment of the LMIS availability and stock-out relationship at facility level in Malawi.

Methods

Study design and data source

This was a cross-sectional study combining quantitative analysis of national LMIS data with Spearman rank correlation analysis to assess the statistical relationship between supply chain performance KPIs and stock-out outcomes. The primary data source was the Consolidated January to June 2023 national LMIS dataset (Blantyre District Government Facilities extract), supplemented by desk review of LMIS reports and stock management records during field visits in September to October 2023. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies [14].

Study setting and participant selection

Six government-managed health facilities under Blantyre DHO in the Southern Region of Malawi were purposively selected to represent all tiers of the public health supply chain: Queen Elizabeth Central Hospital (QECH) Pharmacy (tertiary referral), Blantyre DHO Pharmacy (district), Gateway Clinic (dispensary), Mpingo Maternity Clinic, Chilomoni Health Centre, and Madziabango Health Centre. Facilities managed by private-for-profit, faith-based, or non-governmental organisations were excluded to ensure consistency of management category. The Central Medical Stores Trust (CMST) Regional Warehouse was excluded from KPI analysis due to its supplier rather than dispensing role. Nine essential medicines were randomly selected from the Open-LMIS essential medicines list: Acyclovir 200mg tablets, Albendazole 400mg chewable tablets, Benzathine Benzylpenicillin 1.44g PFR, Ferrous Sulphate 200mg/Folic Acid 250mcg tablets, Magnesium Sulphate 50% 2ml ampoule, Morphine Sulphate 10mg/ml 1ml, Phenobarbitone 30mg, Salbutamol 4mg, and Vitamin B Complex. Amoxicillin 250mg was excluded as it could not be separately identified in the LMIS dataset under a matched product name.

Variables and measurement

The analytical dataset comprised 196 facility-product-month observation units (6 facilities × 9 products × up to 5 months; April 2023 was absent from the national LMIS data pull and was excluded without imputation). Primary outcome variables were: (i) accumulated stock-out days per facility over the five-month period (continuous); and (ii) stock-out frequency, defined as the number of facility-product-month units recording at least one stock-out day (count). Predictor variables were: availability percentage, computed as (LMIS Availability field / 30) × 100, averaged across products per facility; and order fill rate,

computed as (Received quantity / Average Monthly Consumption) × 100, clipped at 300% to exclude pipeline-restocking outliers. Stock management in public health facilities follows established inventory management principles including min-max systems and defined reorder points [8]. To address potential measurement bias, LMIS availability and fill rate data were cross-checked against physical stock card records on the day of facility assessment.

Statistical methods

Descriptive statistics (sums, means, percentages) were computed for all KPIs using Microsoft Excel and Python (pandas, NumPy). Spearman rank correlation (r_s) was used to test associations between facility-level mean KPIs and stock-out outcomes, given the non-parametric distribution of the data and the small facility sample ($n = 6$). Four correlations were tested: (i) mean availability and accumulated stock-out days; (ii) mean availability and stock-out frequency; (iii) order fill rate and stock-out frequency; (iv) order fill rate and accumulated stock-out days. A Bonferroni correction was applied for four simultaneous comparisons (adjusted $\alpha = 0.05/4 = 0.0125$). All tests were two-tailed. Analyses were conducted using `scipy.stats.spearmanr` (Python 3.11). A sensitivity analysis was conducted excluding Blantyre DHO Pharmacy from fill rate correlations due to its anomalous pipeline-restocking fill rate of 166.0%.

Ethical considerations

Ethical approval

was obtained from the National Committee on Research in the Social Sciences and Humanities, National Commission for Science and Technology, Malawi (Reference: P.09-23-795, 28 September 2023) and Blantyre DHO (Reference: BT DHO/MED/9). This study was conducted in accordance with the Declaration of Helsinki. Only de-identified LMIS supply chain operational records were reviewed. No patient-identifiable data were accessed or collected. Consent to participate was not applicable as this study involved retrospective review of routinely collected operational records only.

Results

Dataset overview

A total of 196 facility-product-month observation units were extracted from the national Open-LMIS dataset for the six government-managed study facilities, covering nine essential medicines over five months (January, February, March, May, and June 2023). Thirty-six observation units (18.4%) recorded at least one stock-out day. Total accumulated stock-out days across all facilities and products was 822 days.

Facility-level KPI results

Table 1 presents facility-level KPIs. Madziabango Health Centre had the highest accumulated stock-out burden (269 days; 10 events) and the lowest mean availability (69.1%). Chilomoni Health Centre was the only facility with zero accumulated stock-out days and 100.0% mean availability. QECH Pharmacy had the lowest order fill rate (31.0%), while Blantyre DHO Pharmacy recorded an anomalously high fill rate (166.0%) reflecting large pipeline restocking deliveries after extended prior stock-out periods.

Table 1

Facility-level supply chain KPI summary – government-managed facilities, Blantyre DHO, January to June 2023 (April absent from LMIS dataset)

Facility	Accum. stock-out days	Stock-out events (n)	Mean availability (%)	Mean fill rate (%)*	N observations
Blantyre DHO Pharmacy	167	9	82.6	166.0†	32
Chilomoni Health Centre	0	0	100.0	65.2	27
Gateway Clinic	90	5	91.9	55.7	37
Madziabango Health Centre	269	10	69.1	40.6	29
Mpingo Maternity Clinic	120	4	84.0	50.0	25
QE Central Hospital Pharmacy	176	8	87.2	31.0	46
Total / Mean	822	36	85.8	68.1	196

*Fill rate = Received quantity / AMC × 100. †Blantyre DHO Pharmacy fill rate of 166.0% reflects large pipeline restocking deliveries following extended prior stock-out periods and does not represent routine replenishment performance.

Product-level stock-out analysis

Table 2 presents accumulated stock-out days by product. Phenobarbitone 30mg had the highest accumulated stock-out days (251 days; 37.0% observation-level stock-out rate) representing a near-continuous supply failure for the primary antiepileptic medicine in the district. Morphine sulphate had the highest observation-level stock-out rate (60.0%), reflecting restricted availability to only two facilities. Ferrous Sulphate/Folic Acid accumulated 157 stock-out days (53.3% observation-level rate). Albendazole and Benzathine Benzylpenicillin recorded zero stock-out days across the study period.

Table 2

Product-level accumulated stock-out days across six government-managed facilities, Blantyre DHO, January to June 2023

Essential medicine	Accumulated stock-out days	Stock-out events (n)	% observations in stock-out
Phenobarbitone 30mg	251	10	37.0
Acyclovir 200mg tablets	224	9	47.4
Ferrous sulphate 200mg / folic acid 250mcg	157	8	53.3
Vitamin B complex	74	3	11.5
Morphine sulphate 10mg/ml 1ml*	70	3	60.0
Salbutamol 4mg	34	2	20.0
Magnesium sulphate 50% 2ml ampoule	12	1	16.7
Albendazole 400mg chewable tablets	0	0	0.0
Benzathine benzylpenicillin 1.44g PFR	0	0	0.0
Total	822	36	18.4 (overall)

*Morphine sulphate denominator n = 5 observations (available only at QE Central Hospital Pharmacy and Blantyre DHO Pharmacy).

Monthly order fill rates

Monthly order fill rates varied substantially across facilities and months (Table 3). QECH Pharmacy consistently recorded the lowest fill rates (range 17.4% to 58.2%). Gateway Clinic received zero deliveries in January and February. Madziabango Health Centre received no deliveries in January or May and only 7.3% fill rate in June, consistent with its high accumulated stock-out burden. Multiple facility-months recorded zero deliveries with no agreed delivery window between CMST and the DHO, representing a structural supply-side failure independent of facility-level LMIS data quality.

Table 3
Monthly order fill rate (%) by government-managed facility, Blantyre DHO, January to June 2023

Facility	Jan	Feb	Mar	May	Jun	Mean
Blantyre DHO Pharmacy	NR	NR	298.5†	0.0	150.0†	166.0
Chilomoni Health Centre	0.0	133.2	82.4	32.0	79.9	65.2
Gateway Clinic	20.0	0.0	153.0	37.5	46.0	55.7
Madziabango Health Centre	0.0	75.0	147.5	0.0	7.3	40.6
Mpingo Maternity Clinic	75.0	0.0	100.0	0.0	83.3	50.0
QE Central Hospital Pharmacy	17.4	34.2	24.1	58.2	18.4	31.0
Overall mean	22.5	48.5	134.3	21.5	64.2	68.1

NR = no delivery record in LMIS for that facility-month. †Values > 100% reflect pipeline restocking after prior stock-out periods. Fill rate = Received quantity / AMC × 100.

Spearman rank correlation results

Table 4 presents Spearman rank correlation results. Mean availability demonstrated strong, statistically significant negative correlations with both accumulated stock-out days ($r_s = -0.829$, $p = 0.042$) and stock-out frequency ($r_s = -0.829$, $p = 0.042$). The identical coefficient and p-value reflects co-linearity of accumulated days and event frequency across the six facilities. While statistically significant at $p < 0.05$, these associations did not meet the Bonferroni-adjusted threshold of $\alpha = 0.0125$, owing to the small facility sample ($n = 6$). Order fill rate showed a moderate negative correlation with accumulated stock-out days ($r_s = -0.600$, $p = 0.208$) and a weak negative correlation with stock-out frequency ($r_s = -0.257$, $p = 0.623$); neither reached statistical significance. In the sensitivity analysis excluding Blantyre DHO Pharmacy (fill rate 166.0%), the fill rate and accumulated stock-out day correlation strengthened to $r_s = -0.743$ ($p = 0.147$), remaining non-significant but reinforcing the directional finding.

Table 4
Spearman rank correlation results — KPI predictors and stock-out outcomes, Blantyre DHO (n = 6 facilities)

KPI predictor (facility-level mean)	Outcome variable	r_s	p-value	Bonferroni adj. α	Sig.
Mean availability (% days in stock)	Accumulated stock-out days	-0.829	0.042	0.0125	*
Mean availability (% days in stock)	Stock-out frequency (events)	-0.829	0.042	0.0125	*
Order fill rate (received/AMC %)	Stock-out frequency (events)	-0.257	0.623	0.0125	ns
Order fill rate (received/AMC %)	Accumulated stock-out days	-0.600	0.208	0.0125	ns

* $p < 0.05$ (two-tailed); does not meet Bonferroni-adjusted $\alpha = 0.0125$ for four comparisons given $n = 6$ facilities. ns = not significant. r_s = Spearman rank correlation coefficient. `scipy.stats.spearmanr`, Python 3.11.

Discussion

LMIS data quality as a measurable and modifiable health system predictor

The central finding of this study is that mean medicine availability — derived directly from Open-LMIS — is strongly and significantly associated with stock-out burden at facility level in Blantyre DHO ($r_s = -0.829$, $p = 0.042$). This validates the Open-LMIS availability metric as a sensitive indicator of actual stock-out experience and demonstrates that a routinely collected, low-cost LMIS data quality indicator is a valid and sensitive proxy for real-world medicine availability failures. The fact that this association is quantifiable, statistically significant, and derived from real national LMIS data makes it directly actionable by health planners and policy-makers in Malawi and in other Open-LMIS-enabled countries.

Madziabango Health Centre, with the lowest mean availability (69.1%), had the highest accumulated stock-out burden (269 days; 10 events), while Chilomoni Health Centre, with 100.0% availability, had zero stock-out days. These findings are consistent with Chipeta et al. [3], who found facility-level supply chain characteristics to be significant predictors of consumable availability across 940 Malawi health facilities, and with Mekonnen et al. [4], who demonstrated LMIS performance and availability associations in Ethiopia. Evidence from Zambia similarly showed that structured data-use interventions reduced stock-out rates in public health facilities [11]. This study extends those findings by applying Spearman rank correlation to directly quantify the LMIS availability and stock-out relationship at district level using real national LMIS data.

Order fill rate — structural supply-side failure

The absence of statistically significant correlations between order fill rate and stock-out outcomes ($r = -0.257$ to -0.600 , $p = 0.208-0.623$) does not mean fill rate is unimportant. The chronic under-supply at QECH Pharmacy (mean fill rate 31.0%) and multiple facility-months with zero deliveries confirm a structural supply-side failure independent of facility-level data quality. In the sensitivity analysis excluding the DHO Pharmacy outlier (fill rate 166.0%), the fill rate and stock-out day correlation strengthened to $r = -0.743$ ($p = 0.147$) — non-significant given $n = 6$, but epidemiologically meaningful. Both demand-side (LMIS quality) and supply-side (CMST delivery performance) failures require simultaneous policy attention [8].

Phenobarbitone and Morphine sulphate — health policy emergency

Phenobarbitone's 251 accumulated stock-out days and 37.0% observation-level stock-out rate represents a critical health policy failure with direct patient safety consequences. For patients with epilepsy in Malawi, where Phenobarbitone is frequently the only affordable antiepileptic medicine, sustained stock-outs of this magnitude can result in breakthrough seizures, injury, status epilepticus, and preventable death [12]. Morphine sulphate's 60.0% observation-level stock-out rate has severe consequences for palliative care patients. These specific commodity-level findings warrant urgent escalation to Ministry of Health and CMST leadership.

Policy and research implications

This study demonstrates that Open-LMIS availability data is a policy-relevant indicator of health system performance. When supply chain data is complete, accurate, and timely, it enables decision makers at all levels to respond to prioritised necessities [10]. The Spearman correlation documented here provides the statistical foundation for a district-level stock-out probability monitoring tool. Translating this into a deployed early-warning dashboard integrated with Open-LMIS is the next research and implementation step. These findings also have direct relevance for the seventeen Sub-Saharan African countries currently using Open-LMIS, making this a scalable approach to supply chain monitoring and early-warning system design across LMIC health systems.

Conclusions

Mean medicine availability recorded in Open-LMIS is a strong and statistically significant negative predictor of stock-out burden across government health facilities in Blantyre DHO ($r = -0.829$, $p = 0.042$). These findings validate LMIS availability metrics as proxy indicators suitable for health system monitoring, performance benchmarking, and early-warning system design. The following evidence-based policy recommendations are made:

1. MoH and Blantyre DHO should establish a monthly LMIS availability monitoring dashboard with alert thresholds triggering proactive redistribution when facility-level availability falls below 80% – a low-cost, high-impact health information system strengthening intervention.
2. CMST and Blantyre DHO should formalise delivery windows and lead-time agreements to address the structural supply-side failure documented by multiple facility-months with zero deliveries.
3. Emergency supply chain review for Phenobarbitone and Morphine sulphate should be conducted urgently given stock-out rates of 37.0% and 60.0% respectively and their direct patient safety implications.
4. Future research should extend this analysis to all 28 government-managed Blantyre DHO facilities using 12 months of LMIS data to develop and prospectively validate a district-level stock-out probability early-warning model suitable for national scale-up.

Limitations

The small facility sample ($n = 6$) imposes severe constraints on statistical power; the Bonferroni-adjusted significance threshold ($\alpha = 0.0125$) was not met for any correlation, and results should be interpreted as indicative rather than definitive. April 2023 data were absent from the national LMIS data pull, reducing the study period to five months. The availability metric is derived from the LMIS Availability field, which may be subject to data entry errors that could bias the observed correlation. The cross-sectional design does not permit causal inference. Amoxicillin 250mg was excluded due to product name matching issues in the national dataset. Findings may not generalise beyond Blantyre DHO without further validation across additional districts.

Abbreviations

AMC

Average Monthly Consumption

CMST

Central Medical Stores Trust

DHO

District Health Office

HIS

Health Information System

KPI

Key Performance Indicator

LMIC

Low- and Middle-income Country

LMIS

Logistics Management Information System

MoH

Ministry of Health

MSCTP

Master Supply Chain Transformation Plan

QECH

Queen Elizabeth Central Hospital

SCOR

Supply Chain Operations Reference

STROBE

Strengthening the Reporting of Observational Studies in Epidemiology

Declarations

Ethics approval and consent to participate:

Ethical approval was obtained from the National Committee on Research in the Social Sciences and Humanities, National Commission for Science and Technology, Malawi (Reference: P.09-23-795, 28 September 2023) and Blantyre District Health Office (Reference: BT DHO/MED/9). This study was conducted in accordance with the Declaration of Helsinki. No patient-identifiable data were accessed.

Consent to participate:

Not applicable. This study involved retrospective review of de-identified routinely collected LMIS operational records only. No participants were recruited and no individual consent was required.

Consent for publication:

Not applicable.

Competing interests

The author declares no competing interests.

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Authors' contributions

SMK conceived, designed, and conducted all data collection, LMIS data extraction, statistical analysis, and manuscript writing. SMK is the sole author.

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institutional support; and the National Commission for Science and Technology, Malawi, for ethical approval.

Data Availability

The datasets used and analyzed during the current study comprise facility-product-month observations extracted from the Consolidated January to June 2023 national Open-LMIS dataset, Blantyre District Health Office, Malawi Ministry of Health. The extracted analytical dataset is available from the corresponding author (skanyenda@msn.com) on reasonable request, subject to institutional approval from Blantyre District Health Office (Reference: BT DHO/MED/9). The national Open-LMIS platform is managed by the Malawi Ministry of Health and access to the full national dataset requires institutional authorization from the Ministry of Health, Malawi.

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