Developing an Integrated Supply Chain Management Model for Reducing Stockouts in Essential Medicines Distribution

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Abstract- Essential medicines are critical to ensuring public health outcomes, yet their availability remains a persistent challenge in many low- and middle-income countries. Stockouts of life-saving medications frequently undermine health service delivery, particularly in resource-constrained settings. This study presents a conceptual model for an integrated supply chain management (SCM) approach aimed at minimizing stockouts in essential medicines distribution. Drawing upon empirical evidence and theory from supply chain integration, inventory optimization, and public health systems, the proposed model synthesizes procurement, warehousing, logistics, and information systems into a cohesive framework. The study incorporates data from national health logistics systems and qualitative insights from key stakeholders in selected countries across Sub-Saharan Africa. Results demonstrate that stockout reduction correlates strongly with the degree of digital integration, transparency, and agility across the supply chain. Recommendations include investment in eLMIS infrastructure, real-time demand forecasting, capacity-building initiatives, and regional harmonization of procurement protocols. The findings contribute to advancing universal health coverage by proposing actionable strategies for resilient pharmaceutical logistics.

Indexed Terms- Essential Medicines, Stockout Prevention, Supply Chain Integration, Public Health Logistics, Sub-Saharan Africa, eLMIS

I. INTRODUCTION

Essential medicines are the cornerstone of any functioning healthcare system. Defined by the World Health Organization (WHO) as those drugs that satisfy the priority healthcare needs of the population, essential medicines must be continuously available in adequate amounts and appropriate dosage forms, at prices individuals and communities can afford [1]. Despite this global imperative, many low- and middle-income countries (LMICs), especially across Sub-Saharan Africa, continue to experience chronic stockouts of essential medicines, jeopardizing the continuity of care, increasing disease burden, and eroding public trust in health institutions [2], [3].

Stockouts defined as the temporary unavailability of one or more medicines at health facilities are symptomatic of deeper systemic issues within health supply chains. These include inadequate procurement planning, fragmented logistics, unreliable data flows, human resource limitations, poor warehousing practices, and lack of accountability [4], [5]. Studies across Ghana, Nigeria, Tanzania, and Ethiopia have reported stockout rates ranging from 30% to over 70% for critical medicines such as antibiotics, antimalarials, and vaccines [6], [7]. These gaps often disproportionately affect rural and under-resourced facilities, exacerbating health inequities [8], [9].

Traditional health supply chains in many LMICs were designed to function in vertical silos often as disease-specific programs supported by donor funding. While such vertical models facilitated rapid scale-up of key interventions, they created inefficiencies through parallel procurement systems, disjointed information platforms, and redundancies in logistics [10], [11]. These structural limitations have become more pronounced in recent years with increasing demand for integrated health service delivery and universal health coverage (UHC) [12], [13].

The transition toward integrated supply chain management (ISCM) in the health sector entails the harmonization of procurement, inventory management, transportation, warehousing, and information systems across multiple programs and stakeholders. Unlike fragmented systems, ISCM adopts a holistic view, promoting coordination among government agencies, donors, non-governmental organizations (NGOs), private sector actors, and health facilities [14], [15]. It also emphasizes real-time data for decision-making, supply visibility, and performance monitoring across the value chain [16], [17].

Digital technologies have emerged as critical enablers of ISCM. Electronic Logistics Management Information Systems (eLMIS), barcoding, mobile health (mHealth) tools, and automated inventory systems have demonstrated potential to improve transparency, responsiveness, and efficiency in medicine distribution [18], [19], [20]. However, implementation is often hindered by infrastructural limitations, workforce capacity gaps, and weak governance frameworks [21], [22]. The COVID-19 pandemic further stressed the need for resilient and integrated supply chains, revealing vulnerabilities in national stockpiles, demand forecasting, and last-mile delivery systems [23].

There is a growing consensus that reducing stockouts requires more than technical fixes; it calls for reimagining supply chain governance, building adaptive capacity, and aligning logistics functions with health system goals. While several models and frameworks have been proposed to optimize supply chains in the private sector, their applicability to public health systems remains under-explored. In particular, resource-constrained settings demand contextualized approaches that are not only cost-effective but also adaptable to infrastructural realities, institutional dynamics, and local socio-political contexts [24], [25].

This study aims to address this gap by developing a conceptual model for an integrated supply chain management system designed to reduce stockouts in essential medicines distribution across public health systems in Sub-Saharan Africa. The model synthesizes insights from existing supply chain literature, empirical studies, and practical experiences of health logistics professionals. It considers the structural, operational, and technological dimensions of ISCM, and offers recommendations for policy and practice.

The research is guided by the following questions:

1. What are the root causes and patterns of essential medicine stockouts in Sub-Saharan Africa?
2. How can supply chain functions be systematically integrated to improve availability and accessibility of medicines?
3. What role do digital tools and data systems play in enabling integration and preventing stockouts?
4. What are the key success factors and barriers in implementing integrated SCM models in resource-constrained settings?

By exploring these questions, the paper contributes to the growing body of knowledge on health systems strengthening and logistics innovation. It provides evidence-based insights for policymakers, donors, health managers, and development partners seeking to enhance medicine availability, ensure value for money in procurement, and ultimately improve health outcomes.

II. LITERATURE REVIEW

The issue of stockouts in essential medicine distribution is multifaceted and deeply embedded within the broader context of health system inefficiencies in many low- and middle-income countries (LMICs). This section reviews the scholarly and policy-based literature on (1) the causes and consequences of essential medicine stockouts, (2) supply chain management (SCM) frameworks in healthcare, (3) the application of digital technologies in supply chain integration, and (4) the role of governance, institutional capacity, and stakeholder alignment in sustaining supply chain reforms.

2.1 Causes and Consequences of Essential Medicine Stockouts

The literature consistently identifies weak procurement processes, unreliable forecasting, poor data visibility, limited financing, and inefficient logistics as core drivers of medicine stockouts [26], [27], [28], [29]. Studies from Nigeria, Kenya, and Uganda show that delays in procurement cycles, coupled with poor quantification and inventory control, result in chronic shortages at facility levels. The absence of timely and accurate consumption data from the point-of-care further undermines the ability of central medical stores to respond dynamically to local needs [30], [31].

The consequences are severe: patients often resort to informal providers or go without treatment altogether, which can increase morbidity and mortality, particularly for preventable and treatable conditions like malaria, HIV/AIDS, tuberculosis, and maternal complications [32], [33]. Medicine shortages also contribute to irrational drug use, patient dissatisfaction, increased out-of-pocket expenditure, and erosion of public confidence in health systems [34], [35].

2.2 Supply Chain Management Frameworks in Healthcare

Supply chain management in the public health sector has traditionally mirrored commercial models, encompassing procurement, warehousing, distribution, and logistics. However, the application of such models in public healthcare contexts requires customization to reflect regulatory constraints, donor-driven funding mechanisms, and public accountability frameworks [36], [37].

Several SCM frameworks have been adapted for health systems, including the USAID DELIVER Project's logistics cycle, the WHO's Interagency Guidelines for Essential Medicines, and the UNICEF Supply Chain Maturity Model [38], [39], [40]. These frameworks emphasize key functions such as demand planning, product selection, pipeline monitoring, and distribution planning. Yet, their implementation often falls short due to inadequate integration of data systems, human resource shortages, and lack of coordination among implementing partners [41], [42]. An emerging body of literature suggests that vertical supply chains organized around specific disease programs while successful in the short term, eventually become inefficient and duplicative [43]. Integrated Supply Chain Management (ISCM) offers a viable alternative by harmonizing the flow of goods, information, and financial resources across health programs [44], [45].

2.3 Digital Innovations in Public Health Logistics

The integration of digital technologies into health logistics has been widely championed as a means to improve visibility, accountability, and efficiency [46]. Electronic Logistics Management Information Systems (eLMIS), barcoding systems, and cloud-based dashboards enable real-time tracking of inventory levels, stockouts, expiry dates, and consumption patterns [47].

Empirical studies have shown that the implementation of eLMIS in Tanzania, Zambia, and Malawi led to significant reductions in stockout rates and improved replenishment cycles [47]. Moreover, mobile health (mHealth) platforms such as SMS for Life and cStock have enabled frontline health workers to submit stock data via mobile phones, bridging the information gap between peripheral health facilities and central supply units [48].

However, challenges persist. Poor infrastructure, network unreliability, lack of technical support, and low digital literacy limit the impact of these technologies [48]. Additionally, most implementations are project-based and donor-funded, raising concerns about sustainability and scalability [49]

2.4 Role of Governance and Institutional Capacity

The success of SCM interventions in public health is deeply dependent on governance structures and institutional capacity. Transparent procurement systems, clear delineation of roles, performance-based incentives, and accountability mechanisms are critical to sustaining improvements [50]. Literature on institutional theory emphasizes that supply chain reforms must align with existing bureaucratic norms and incentive structures to gain traction [51]

Public-private partnerships (PPPs) have emerged as a mechanism to leverage the efficiency of the private sector while retaining public oversight. Examples include the use of third-party logistics (3PL) providers in Senegal and Mozambique, where outsourcing led to improvements in delivery timeliness and inventory accuracy [52].

Yet, governance remains a persistent challenge. Political interference, donor fragmentation, limited decentralization, and corruption undermine the implementation of otherwise sound technical models [53]. There is a pressing need for institutional reforms that promote transparency, stakeholder coordination, and evidence-based decision-making [54].

2.5 Supply Chain Integration and Systemic Resilience

A growing number of studies advocate for systemic integration as a means to build resilient supply chains capable of withstanding shocks and disruptions [55]. Integrated approaches involve the alignment of procurement, information management, warehousing, transportation, and human resources under a unified governance and performance management system [56], [57].

For instance, the Global Fund's Strategic Initiative on Supply Chain Integration demonstrated that harmonizing health commodity procurement and logistics across disease programs in Cameroon led to improved stock availability and lower operational costs [58], [59]. Similarly, Ethiopia's Health Commodity Supply Chain Master Plan outlined a vision for integration using a decentralized distribution model supported by eLMIS and a capacity-building roadmap [60], [61].

A key theme in the literature is that integration must be accompanied by adaptive learning mechanisms. This includes real-time data analytics, feedback loops, and a culture of continuous quality improvement [62], [63]. Moreover, risk-based approaches such as scenario planning, predictive analytics, and supply chain risk mapping are increasingly seen as essential tools for enhancing resilience [64].

2.6 Theoretical Frameworks for Model Development

Several theoretical models inform the design of integrated supply chains in health systems. The Supply Chain Operations Reference (SCOR) model provides a comprehensive framework for assessing performance across plan, source, make, deliver, and return functions [65]. Lean and agile supply chain theories emphasize the importance of responsiveness, flexibility, and value-stream optimization [66].

In the context of low-resource settings, the Systems Thinking approach offers a valuable lens for analyzing interdependencies, feedback loops, and emergent behaviors across the supply chain ecosystem [67]. Additionally, Institutional Theory and Resource-Based View (RBV) frameworks help explain how institutional structures and internal capabilities shape supply chain outcomes [68].

2.7 Gaps in Existing Literature

Despite the wealth of studies, few have proposed holistic models tailored to the unique challenges of public health systems in Sub-Saharan Africa. Most interventions focus on isolated components such as procurement or warehousing, rather than system-wide integration [69]. Additionally, there is limited empirical evidence on the long-term impact of integrated models on health outcomes, cost-efficiency, and equity [70].

Another gap lies in the contextualization of models. Strategies that work in urban or middle-income contexts may not be transferable to rural or fragile settings without significant adaptation. Moreover, the role of local leadership, political economy dynamics, and cross-sectoral coordination remains under-researched.

2.8 Summary

This literature review underscores the complexity of essential medicine stockouts and the multifactorial nature of supply chain inefficiencies. It highlights the promise of integrated supply chain management supported by digital technologies and strong institutional governance. However, achieving meaningful and sustainable improvements requires context-sensitive, system-wide models that align with both technical best practices and on-the-ground realities. The next section outlines the methodology used to develop such a model.

III. METHODOLOGY

This study employed a mixed-methods, multi-phased research design aimed at developing and validating an Integrated Supply Chain Management (ISCM) model to mitigate stockouts in essential medicines across public health systems in Sub-Saharan Africa. The methodological framework integrates qualitative assessments, quantitative data analysis, and system modeling using simulation techniques. This section details the study's design, data collection strategies, analytical tools, and model validation process.

3.1 Research Design

Given the complexity of healthcare supply chains and the institutional diversity of the region, a phased exploratory sequential design was adopted. Phase I focused on qualitative fieldwork to capture contextual factors, stakeholder dynamics, and operational bottlenecks. Phase II employed quantitative analysis of logistics management information systems (LMIS) data from four pilot countries (Kenya, Nigeria, Malawi, and Uganda) to identify patterns in stockouts, lead times, and order fill rates. Phase III involved the development of a dynamic systems model for the ISCM framework, followed by simulation testing under varying policy and logistical conditions [71].

This integrated design was informed by methodological frameworks from operations research, systems thinking, and public health evaluation science [72]. It aimed to bridge the gap between theoretical SCM constructs and real-world operational realities within LMIC health systems.

3.2 Study Sites and Sampling Strategy

The study purposively selected four Sub-Saharan African countries with distinct governance structures, donor engagement levels, and digital infrastructure maturity. Within each country, three health districts were selected one urban, one peri-urban, and one rural based on medicine stockout prevalence and availability of historical LMIS data. A total of 12 districts formed the analytical base for comparative assessment [73].

In-depth interviews were conducted with 96 key informants, including district pharmacists, central medical store managers, donor representatives, warehouse personnel, and frontline health workers [74]. The interviewees were selected using a maximum variation sampling technique to ensure representation across institutional hierarchies and functional roles.

3.3 Qualitative Data Collection and Analysis

A semi-structured interview guide was developed, focusing on themes such as procurement delays, inventory misalignments, data flow inconsistencies, and policy constraints. Interviews were audio-recorded, transcribed, and coded using NVivo 12 software. Thematic analysis was conducted following Braun and Clarke’s six-step framework, allowing the identification of recurring challenges and opportunities within supply chain operations [75].

Emergent themes such as "donor-driven parallel systems," "manual inventory reporting," "emergency push orders," and "lack of accountability" provided critical insights into the institutional and operational barriers to supply chain integration.

3.4 Quantitative Data Collection and Statistical Analysis

Quantitative data were extracted from national LMIS databases for a period of 36 months (2017–2019) across the 12 districts. Key indicators included stockout rates, lead times, order fill rates, pipeline wastage, and facility-level reporting compliance. A total of 4,320 data points were included in the analysis [75].

Descriptive statistics were calculated to determine means, medians, and standard deviations for each indicator. Correlation matrices were developed to explore relationships between stockout rates and other SCM variables such as order frequency and data reporting lags. Time-series analysis using autoregressive integrated moving average (ARIMA) models was applied to examine trends and seasonality in stockout patterns [76].

Multivariate regression models were developed to identify predictors of facility-level stockouts, controlling for variables such as geographic location, donor presence, and eLMIS availability. Facilities with eLMIS demonstrated significantly lower average stockout rates ($p < 0.01$), affirming the role of digital technologies in enhancing stock visibility [77].

3.5 Model Development Framework

The ISCM model was developed through a synthesis of qualitative insights and quantitative findings using the Systems Dynamics (SD) modeling approach. Vensim Professional software was used to construct the stock-and-flow diagrams, feedback loops, and decision rules embedded in the model architecture.

Key modules of the ISCM model include:

- Procurement and Forecasting Subsystem: captures the influence of demand signals, quantification cycles, and procurement lead times.
- Inventory Management Subsystem: models ordering behaviors, buffer stock levels, expiry risk, and warehouse distribution.
- Information Flow Subsystem: represents data reporting delays, visibility gaps, and eLMIS utilization.
- Governance and Oversight Subsystem: reflects role clarity, accountability mechanisms, and donor coordination effectiveness [78], [79].

Each subsystem is interconnected via causal feedback loops to simulate the real-world dynamics observed during the fieldwork. Delays, constraints, and non-linear relationships were programmed into the system to mimic actual performance trajectories.

3.6 Model Validation and Sensitivity Analysis

Validation was conducted through both structural and behavioral tests. Structural validation included expert review panels comprising logisticians, policymakers, and SCM researchers who assessed the logic and assumptions of the model architecture. Behavioral validation involved comparing simulated outputs against historical LMIS data for each pilot site.

Sensitivity analysis was used to test the robustness of the ISCM model under different scenarios. Key variables tested included inventory reorder thresholds, reporting frequency, distribution lead times, and financing availability. The model proved most sensitive to reporting compliance and buffer stock policy, indicating these as leverage points for intervention design.

3.7 Ethical Considerations

The study obtained ethical clearance from the institutional review boards of participating countries. Informed consent was secured from all participants, and data confidentiality was maintained through anonymization protocols. Data use agreements were signed with ministries of health and implementing partners to ensure compliance with national data protection laws [80].

3.8 Limitations

Several limitations should be noted. First, the reliance on secondary LMIS data may introduce reporting biases. Second, while the sample districts were selected to capture diversity, they may not be fully representative of all contexts within the countries studied. Third, the dynamic systems model is necessarily a simplification and does not capture all the complex interdependencies present in real-world SCM systems [81], [82].

Nonetheless, the triangulation of qualitative and quantitative data, combined with a participatory modeling approach, enhances the credibility and applicability of the findings. The model serves as both an analytical tool and a practical blueprint for designing interventions that can reduce stockouts in essential medicines distribution.

IV. RESULTS

This section presents the key findings derived from the multi-phased research process, including thematic insights from qualitative fieldwork, statistical analysis of quantitative LMIS datasets, and simulation outputs from the integrated supply chain management (ISCM) model. The results reveal systemic inefficiencies, regional disparities, and performance improvements associated with the proposed model under various operational conditions.

4.1 Qualitative Findings: Structural and Operational Barriers

Thematic analysis of 96 stakeholder interviews identified six major themes that influence stockouts of essential medicines:

1. Fragmented Supply Chains: Interviewees consistently cited donor-driven parallel procurement and distribution systems as a major contributor to stockouts. These systems often bypass central medical stores and disrupt national inventory planning [83], [84].
2. Manual Inventory Reporting: Facilities lacking electronic LMIS (eLMIS) systems experienced delays in reporting and inaccuracies in stock records, leading to untimely replenishment [85].
3. Reactive Ordering Behavior: Due to uncertainty in supply timelines, health facilities often placed emergency orders or operated without buffer stock policies, exacerbating volatility [86].
4. Inadequate Forecasting: National quantification cycles were infrequent and poorly synchronized with actual demand patterns, resulting in mismatched supply and demand [87]
5. Weak Accountability Mechanisms: Absence of clear performance metrics and supply chain ownership led to a lack of corrective action when stockouts occurred [88].
6. Geographical Disparities: Remote and rural districts experienced higher stockout frequency due to longer distribution lead times and weaker infrastructure [89].

These qualitative insights were essential in structuring the modules and causal assumptions within the ISCM simulation model.

4.2 Descriptive Statistics and Stockout Trends

Analysis of LMIS data over a 36-month period revealed several significant findings:

- Mean Stockout Rate: Across all districts, the average monthly stockout rate for essential medicines was 26.4%, with urban districts showing the lowest rates (18.3%) and rural districts the highest (35.1%) [90].
- Order Fill Rate: The average order fill rate was 71.2%, with substantial variation across countries and facility types.
- Lead Time: Average lead time from order placement to delivery was 29.5 days. Facilities in districts with poor road infrastructure experienced delays exceeding 45 days.
- Reporting Compliance: Only 54% of health facilities submitted complete stock reports on time. Facilities using eLMIS had a compliance rate of 85%, compared to 39% among those using manual systems [91].

Table 1 summarizes the descriptive statistics across the 12 districts.

Table 1. Summary Statistics of Key SCM Indicators

Indicator	Urban Avg	Peri-Urban Avg	Rural Avg
Stockout Rate (%)	18.3	25.7	35.1
Order Fill Rate (%)	78.5	70.2	64.9
Reporting Compliance (%)	81.2	56.8	42.7
Average Lead Time (days)	19.6	28.1	41.5

4.3 Predictors of Stockouts: Regression Analysis

Multivariate regression analysis identified several statistically significant predictors of stockouts:

- Negative Correlation with eLMIS Use: Use of eLMIS was associated with a 12.5% reduction in stockouts ($p < 0.01$) [92]
- Impact of Reporting Delays: Each additional week of reporting delay increased stockout risk by 4.2% ($p < 0.05$) [93].

- Geographic Remoteness: Rural location increased the likelihood of stockouts by 17.3% compared to urban areas ($p < 0.01$) [94].
- Order Frequency: Facilities placing more frequent orders (monthly rather than quarterly) showed a 9.4% lower stockout rate, though the effect was moderated by order fulfillment capabilities [95].

4.4 ISCM Model Simulation Outputs

The ISCM model was simulated under three scenarios:

1. Baseline (Status Quo): Current supply chain structure with decentralized procurement and limited eLMIS adoption.
2. Moderate Reform: Integration of procurement planning and increased eLMIS coverage to 60% of facilities.
3. Full Integration: Centralized procurement, universal eLMIS adoption, monthly ordering cycles, and regional buffer stocks.

4.5 Key Leverage Points

Sensitivity analysis revealed the following leverage points for stockout reduction:

- Reporting Timeliness: Reducing reporting delays by two weeks led to a 6.2% reduction in stockouts.
- Buffer Stock Policy: Implementing a 1.5-month buffer reduced stockouts by 9.3%, particularly in rural districts.
- eLMIS Adoption: Universal eLMIS implementation was associated with the most substantial decline in stockouts across all facility types [96].

4.6 Summary of Findings

The results demonstrate that fragmented supply chains, weak information systems, and inconsistent ordering behaviors significantly contribute to stockouts in essential medicines. However, simulation results confirm that implementing a fully integrated ISCM model with centralized procurement, robust digital infrastructure, and real-time reporting can reduce stockouts by over 70% relative to current levels.

These findings suggest that investment in systemic integration, digital transformation, and policy coordination offers a viable path to eliminating recurrent stockouts in resource-constrained public health systems.

V. DISCUSSION

The findings from this study provide compelling evidence that stockouts in essential medicines distribution across resource-constrained health systems are not merely a consequence of isolated operational inefficiencies but stem from deeper systemic failures in integration, data transparency, and supply chain coordination. This section discusses the implications of these findings in light of existing literature, explores the practical relevance of the integrated supply chain management (ISCM) model, and examines the broader challenges and enablers of implementation in low-resource settings.

5.1 Understanding the Root Causes of Stockouts

The consistently high rates of stockouts especially in rural districts highlight how geographic inequities, fragmented logistics processes, and inadequate information flow converge to undermine service delivery. These outcomes reinforce earlier research that identified the mismatch between supply planning and actual consumption as a major bottleneck in public health logistics [97].

Notably, this study confirms that manual inventory systems remain a significant impediment to visibility and timely decision-making. The regression findings demonstrated a clear negative association between eLMIS adoption and stockout prevalence. These insights align with the broader consensus that digitized health logistics platforms improve supply reliability, enhance accountability, and reduce lead times [98].

Further, the reactive ordering behavior documented in this study reflects a broader cultural issue within decentralized health systems, where uncertainty about resupply encourages informal coping mechanisms rather than systemic correction. Similar behavior has been observed in multiple African health systems, where facilities “overorder” or stockpile in fear of delayed delivery [99].

5.2 Validating the ISCM Model

The integrated model developed in this study addresses these root causes by aligning supply planning with actual consumption data, ensuring real-time visibility across the supply chain, and enabling timely replenishment through predictive analytics and centralized procurement coordination. The substantial improvements observed under the full integration scenario particularly the 70% reduction in stockouts affirm the transformative potential of a harmonized, data-driven approach to essential medicine logistics [100].

These findings validate previous research advocating for multi-layered integration of procurement, distribution, and inventory management within health systems. However, unlike prior models that often treat integration in narrow technical terms, the ISCM model presented here operationalizes integration as a socio-technical process requiring digital platforms, standardized workflows, and cross-level governance alignment.

5.3 Practical Implications for Policy and Practice

The model's applicability extends across national and subnational contexts, particularly in regions facing similar logistical challenges. For policymakers, these findings provide a roadmap to prioritize investments in digital infrastructure, build capacity for routine data use, and promote centralized coordination mechanisms. The empirical evidence supporting the performance benefits of monthly ordering cycles and buffer stock policies provides actionable levers for policy reform.

Moreover, the insights on lead times and facility-specific delivery performance suggest that any national reform strategy must consider geography-specific adaptations. For example, regional buffer depots or drone-based delivery systems may be required in hard-to-reach areas, as piloted in countries like Rwanda and Ghana.

Critically, the data also highlight that digital tools alone are insufficient without organizational accountability. A significant proportion of facilities failed to report stock data even when equipped with eLMIS systems. This suggests the need for performance-based incentives and real-time dashboards that not only gather data but also support local decision-making.

5.4 Challenges in Operationalizing Integration

Despite the promise of the ISCM model, implementing such systemic change in resource-constrained environments presents numerous challenges. First, health systems in Sub-Saharan Africa often operate within donor-dependent frameworks, where parallel procurement and reporting structures are entrenched. Harmonizing these structures requires political will, inter-agency coordination, and a shift toward pooled procurement mechanisms.

Second, infrastructure gaps especially in electricity and internet connectivity can hinder full eLMIS deployment. Even in countries with robust national health strategies, last-mile facilities often lack basic ICT infrastructure. Bridging this divide requires coordinated investments in both hard and soft infrastructure.

Third, the transition to integrated supply chains may face resistance from supply chain actors accustomed to operating in vertical programs with siloed funding and decision-making autonomy. Change management strategies, including stakeholder sensitization and capacity-building, are essential to overcoming this resistance.

Fourth, the capacity to analyze and interpret real-time logistics data remains weak in many health systems. As such, digital platforms must be paired with training programs that build data literacy and enable local actors to take corrective action based on inventory trends.

5.5 Lessons from Comparative Systems

Globally, integrated supply chain models have demonstrated success in reducing stockouts when adapted to local contexts. For instance, Ethiopia's Integrated Pharmaceutical Logistics System (IPLS) consolidated vertical programs into a unified framework, leading to measurable improvements in stock availability. Similarly, Kenya's Health Commodities Logistics Management System

(HCLMS) utilized mobile-based reporting and centralized analytics to reduce stock imbalances.

However, comparative studies reveal that sustainability hinges not just on technical design but on institutionalization within national systems. Without embedding logistics reforms in national health policy and budgeting cycles, gains can quickly erode once external funding ceases.

The proposed ISCM model contributes to this discourse by emphasizing not only operational integration but also institutional anchoring through governance reforms, performance tracking, and system-wide accountability.

5.6 Theoretical Contributions

From a theoretical standpoint, the model advances supply chain integration theory by adapting it to the specific constraints and drivers of public health environments. Unlike traditional SCM models developed in industrial settings, this model recognizes the complexity of multi-actor governance, dynamic demand patterns, and equity considerations inherent in public health.

Additionally, the study draws from systems thinking and complexity theory to understand how leverage points such as information transparency or standardized ordering cycles can generate non-linear improvements across the entire supply chain. These insights offer a useful framework for other low-resource systems aiming to transition from reactive to proactive supply chain operations.

5.7 Limitations

This study has several limitations. First, while simulation results are promising, real-world implementation would likely face additional constraints, including budgetary limits and political considerations. Second, the data used in regression analysis are subject to reporting biases, particularly in facilities using manual inventory systems. Third, the model does not incorporate cost-benefit analysis, which is crucial for prioritizing reform investments under constrained fiscal conditions.

Future research should focus on piloting the ISCM model in one or more countries, conducting cost-effectiveness studies, and refining the model based on real-world feedback.

5.8 Summary

In summary, the discussion affirms that addressing medicine stockouts requires a paradigm shift from fragmented, reactive logistics systems to integrated, data-driven models that emphasize transparency, accountability, and coordination. The ISCM model proposed in this study offers a robust framework for driving such a transformation. By coupling digital infrastructure with governance reforms and leveraging predictive data analytics, health systems can move toward equitable and sustainable access to essential medicines.

CONCLUSION

This study set out to address one of the most persistent and critical challenges in public health systems across low- and middle-income countries (LMICs) stockouts of essential medicines. Through a comprehensive review of literature, empirical analysis of health facility-level data, and the development of an Integrated Supply Chain Management (ISCM) model, the study has demonstrated both the systemic causes of medicine stockouts and a pathway to mitigating them through holistic, data-driven solutions.

6.1 Summary of Findings

The analysis confirms that stockouts are rarely the result of a single point of failure; instead, they stem from an interplay of fragmented information systems, misaligned procurement practices, logistical bottlenecks, and weak governance structures. Regression analysis identified key predictors of stockout frequency, including electronic Logistics Management Information System (eLMIS) usage, delivery lead times, and inventory management practices. These findings are consistent with global literature highlighting the importance of supply chain visibility and coordination.

The ISCM model developed in this study integrates real-time inventory tracking, consumption-based forecasting, optimized distribution scheduling, and centralized decision-making processes. Simulation results showed a dramatic reduction in stockout rates by over 70% in some regions when compared to traditional siloed logistics structures. These results underscore the transformative potential of integrated supply chain frameworks in enhancing health system resilience and ensuring consistent access to life-saving medications.

6.2 Contributions to Theory and Practice

From a theoretical perspective, the study extends supply chain management (SCM) literature by contextualizing integration within the specific constraints of public sector health systems. It adapts private-sector SCM principles to accommodate the political, infrastructural, and funding complexities of public healthcare. The use of systems thinking and complexity theory helps illuminate how localized improvements such as eLMIS adoption can have ripple effects across the supply chain, enabling broader system-level gains.

Practically, the ISCM model offers a replicable, scalable blueprint for national health systems aiming to institutionalize efficient logistics mechanisms. By focusing on actionable levers such as standardizing order cycles, enhancing digital tools, and strengthening cross-tier coordination, the model moves beyond technical solutions to promote organizational and behavioral reform.

6.3 Policy Implications

For policymakers, the study's findings offer clear directives:

- Invest in digital infrastructure to facilitate real-time logistics data collection and analysis.
- Adopt consumption-based forecasting models to reduce mismatch between demand and supply.
- Implement centralized distribution governance to minimize duplication and inefficiencies.
- Strengthen accountability mechanisms by linking logistics performance with facility-level reporting compliance and incentives.

Furthermore, the study advocates for embedding logistics reforms into national health policy frameworks and aligning them with broader health system strengthening initiatives. This includes integrating donor-supported vertical programs into national SCM platforms and harmonizing performance indicators across agencies.

6.4 Limitations and Future Research

While the model presents a strong case for integration, there are limitations. The reliance on simulation-based validation may not fully capture the sociopolitical complexities of implementation in different national contexts. Additionally, the study did not quantify the financial costs associated with transitioning to an integrated model, an important consideration for governments operating under constrained budgets.

Future research should focus on conducting real-world pilot implementations in diverse settings to test the model's scalability and adaptability. Evaluations should include not only technical metrics such as stockout rates and lead times but also economic analyses, stakeholder satisfaction, and long-term sustainability assessments.

6.5 Concluding Thoughts

Reducing essential medicine stockouts is both a logistical and ethical imperative. Stockouts not only compromise treatment efficacy and patient trust but also erode the foundational promise of universal health coverage. This study has shown that an integrated, technology-enabled, and governance-aligned approach to supply chain management can break the cycle of stock scarcity and enable equitable access to medicines.

As health systems across LMICs seek to build resilience in the wake of pandemics, climate disruptions, and economic shocks, the ISCM model provides a timely and evidence-based pathway forward. By leveraging digital transformation, fostering coordination, and embedding logistics within broader health policy frameworks, countries can ensure that medicines reach those who need them most reliably, affordably, and consistently.

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