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EXPLORING EXPERT SYSTEMS AND THEIR APPLICATIONS IN THE PHARMACEUTICAL INDUSTRY IN NIGERIA

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ABSTRACT

Pharmaceutical retail organizations are critical to healthcare access and medication availability, yet many continue to experience stock-outs, overstocking, expiry losses, and supply-chain inefficiencies. This study systematically reviewed literature on Decision Support Systems (DSS), Expert Systems (ES), and Inventory Management Systems (IMS) to evaluate their application, integration, and outcomes in pharmaceutical retail settings globally. A systematic review guided by PRISMA identified 149 records, screened 104 unique studies, and included 91 eligible publications spanning 2015–2025. Evidence was synthesized using a mixed approach that combined descriptive statistical analysis, covering publication trends, technologies adopted, geographic distribution, and reported outcomes, with thematic synthesis to identify dominant system architectures, benefits, barriers, and research gaps. The findings reveal strong global growth in DSS–IMS research, driven largely by artificial intelligence and machine learning, and increasing interest in integrated decision-support frameworks. However, Nigeria-specific evidence indicates continued reliance on basic inventory tools with limited predictive or expert-system capabilities, constrained by infrastructural deficits, high implementation costs, weak policy enforcement and limited technical expertise. The study's contribution lies in foregrounding Nigeria within the global DSS–IMS discourse and consolidating fragmented evidence into a context-sensitive foundation for system design. It highlights the urgent need for scalable, integrated DSS–IMS frameworks incorporating real-time analytics, expert-system intelligence and regulatory alignment to improve inventory performance, patient safety and operational resilience in resource-constrained pharmaceutical retail environments.

Keywords: Expert Systems, Inventory Management, DSS, AI, Pharmaceutical Retail, Nigeria, System Integration

INTRODUCTION

The function of inventory management is described as the attempt to keep raw materials, work-in-progress, and finished goods at levels that ensure maximum service at minimum cost (Wang, 2015; Sterman & Dogan, 2015). The idea seems simple, but reality proves otherwise; in many developing regions, weak regulation and persistent inefficiencies leave pharmacies struggling. Problems include expired medicines, counterfeit products, or even empty shelves where critical drugs should be, all of which are of particular concern for public health.

Pharmaceutical retail organizations play a critical role in ensuring continuous access to safe and effective medicines. In Nigeria, however, persistent challenges such as stock-outs, overstocking, medicine expiries, counterfeit circulation, and poor inventory visibility continue to undermine service quality, patient safety, and operational sustainability. These problems are exacerbated by fragmented inventory practices and limited use of intelligent decision-support technologies capable of handling uncertainty, demand variability, and regulatory complexity in pharmaceutical supply chains. Therefore, the correct inventory management has become essential, especially in organizations dedicated to retail (Ishfaq et al, 2016; Kembro & Norrman, 2019 & Hançerlioğulları et al, 2016).

Decision Support Systems (DSS), Expert Systems (ES), and Inventory Management Systems (IMS) have been widely applied to improve inventory accuracy, forecasting, and managerial decision-making in pharmaceutical and healthcare settings. Globally, advances in artificial intelligence, machine learning, and real-time analytics have enabled the development of integrated DSS–IMS frameworks that outperform standalone inventory tools. However, evidence from Nigeria and much of sub-Saharan Africa indicates a significant gap between global system capabilities and local practice, where pharmacies still rely largely on basic, non-predictive inventory systems with minimal expert or analytical intelligence. Decision Support Systems (DSS) are interactive, computer-based tools meant to guide decision makers in handling complex problems, often by pulling together data, models and stored knowledge. The earliest versions date back to the 1960s and 1970s, when scholars were interested in supporting semi-structured or even unstructured choices where human judgment could not be replaced (Power, 2002; Turban et al., 2018).

The conceptual foundations of DSS emerged from the management information systems (MIS) discourse. Gorry and Scott Morton's classic framework (1971) distinguished structured, semi-structured, and unstructured decisions and argued for computer support beyond routine reporting—setting the agenda for interactive, model-driven systems that help managers think, not just record. Sprague (1980) then articulated a widely adopted "data–model–dialog" view and a development framework that unified users, technology, and organizational processes, codifying DSS as a distinct field rather than a mere extension of MIS.

Expert systems are knowledge-based programs that emulate human expertise via rules and inference. They formed one of the earliest intelligent DSS streams. DENDRAL (mid-1960s) is often recognized as the first scientific expert system, using heuristic search and domain knowledge to infer molecular structures from mass spectra (Stanford/Feigenbaum–

Lederberg–Buchanan). MYCIN (1970s) demonstrated rule-based medical consultation and introduced uncertainty handling (certainty factors) and later EMYCIN as a shell for broader use. XCON/R1 (1980s) became the first large-scale commercial success at DEC, configuring VAX systems with thousands of rules and delivering documented operational savings. These exemplars established the feasibility and limits of codifying expert knowledge at scale.

Inventory theory matured earlier than DSS as formal models: Harris's EOQ (1913) optimized order sizes by balancing setup and holding costs; Wilson (1934) popularized and extended the approach. The 1970s brought Materials Requirements Planning (MRP; Orlicky) and, in the 1980s, MRP II (Wight) integrated capacity/finance, paving the way to ERP suites (e.g., SAP). Lean/JIT methods, associated with Taiichi Ohno's Toyota Production System, shifted emphasis from batch economics to flow, pull, and waste elimination; information systems (barcodes/UPC in 1973; later RFID/EPC) enabled real-time inventory visibility and replenishment.

By the 1990s–2000s, ERP, SCM, WMS, and APS systems embedded optimization, forecasting, and simulation bringing DSS techniques (what-if, scenarios) to inventory decisions (policy selection, safety stocks, multi-echelon control). Contemporary systems incorporate machine learning for demand sensing, IoT for telemetry, and rule/knowledge components for exceptions—essentially hybrid decision support that blends statistical learning and codified policy.

Across Africa, health supply chains have led the formalization of inventory information systems and DSS-like analytics, often through electronic Logistics Management Information Systems (eLMIS). Multi-country programs (e.g., OpenLMIS-based deployments) and donor-supported platforms built dashboards for stock status, pipeline, and resupply decisions; these platforms created precedents for structured decision support in the public sector. Water resources planning and agriculture have also used DSS, though unevenly, with pockets of strong practice (e.g., national or basin-level planning tools) but limited institutionalization compared to health.

Integration of DSS into pharmacy retail has already produced noteworthy results. In developed countries, AI-supported DSS reduced stock wastage by as much as 30% while also raising service standards (Gupta & Kohli, 2019). But in many developing economies, uptake is still very low, mainly because of high setup costs, shortage of skilled workers, and weak infrastructure (Akinboade et al., 2020). Globally, advancements such as AI-driven forecasting, IoT tracking, and blockchain authentication have transformed pharmaceutical inventory systems. However, adoption remains uneven, especially in Nigeria, where infrastructure challenges and limited digital capacity restrict advanced system deployment.

This gap motivates the present review. While a growing body of literature documents DSS–IMS innovations and outcomes in high-income settings, there is limited synthesized evidence explaining how these systems have been applied, integrated, and evaluated in pharmaceutical retail contexts relevant to Nigeria, or why adoption remains slow despite demonstrated benefits. Existing studies are fragmented across disciplines, focus predominantly on developed economies, and rarely address infrastructural, regulatory, and capacity constraints that shape system performance in low-resource environments. As a result, decision-makers lack a consolidated evidence base to guide the design of context-sensitive, scalable DSS–IMS solutions for Nigerian pharmaceutical retail.

Accordingly, this study conducts a systematic literature review to synthesize 10 years of global and regional evidence on DSS, ES, and IMS in pharmaceutical retail, with Nigeria positioned at the center of analysis rather than as a peripheral case. By integrating descriptive and thematic evidence, the review seeks to clarify research trends, system outcomes, barriers to adoption, and unresolved gaps that must be addressed to improve inventory performance and patient safety in developing economies.

This review is guided by the following objectives:

i. To examine global and regional trends in the application of DSS, ES, and IMS in pharmaceutical retail settings.
ii. To synthesize reported outcomes and benefits of DSS–IMS integration for inventory performance and decision-making.
iii. To identify key barriers limiting adoption and effectiveness of intelligent inventory systems in Nigeria and similar low-resource contexts.
iv. To highlight research gaps and system design requirements for scalable, context-sensitive DSS–IMS frameworks suited to Nigerian pharmaceutical retail.

MATERIALS AND METHODS

This study adopted a systematic literature review (SLR) design, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, reproducibility, and methodological rigor. The review focused on published evidence addressing Decision Support Systems (DSS), Expert Systems (ES), Inventory Management Systems (IMS), and their integration within pharmaceutical retail contexts, with particular attention to implications for Nigeria and similar low-resource environments.

Data Sources and Search Strategy

A comprehensive search was conducted across major academic databases, including Scopus, Web of Science, IEEE Xplore, ACM Digital Library, PubMed, ScienceDirect, SpringerLink, and Wiley Online Library. To capture policy-relevant and practice-oriented evidence, grey literature sources were also consulted, including Google Scholar, World Health Organization reports, World Bank publications, and regulatory documents from Nigeria's National Agency for Food and Drug Administration and Control (NAFDAC) and the Pharmacists Council of Nigeria (PCN).

Search strings combined controlled vocabulary and keywords related to decision support systems, expert systems, inventory management, pharmaceutical retail, pharmacy, AI, and Nigeria. Boolean operators ("AND", "OR") were applied to refine retrieval. The search covered publications from 2015 to 2025, with earlier seminal works included selectively for conceptual grounding.

Screening Outcomes

A systematic search of the literature was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

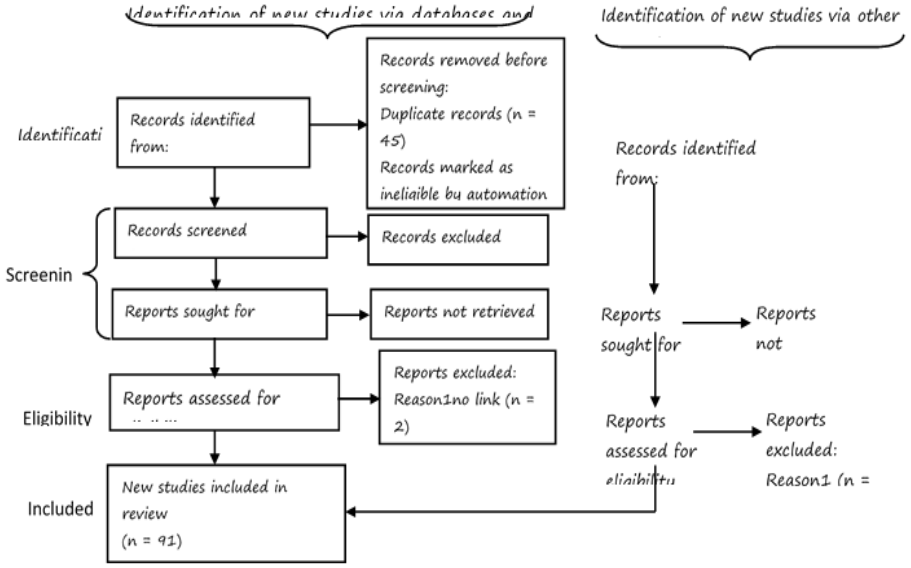

Figure 1: PRISMA Flow Diagram

Altogether, 95 full-text articles were examined in detail. Out of these, 4 were excluded after close reading—2 because they had no real link to pharmaceutical retail, and another 2 because they turned out to be grey literature that didn't meet the review's quality standards. Still, though not without a little frustration, these kinds of exclusions are typical in systematic reviews.

The PRISMA flow diagram (Fig. 1) was used to show the whole path: how studies were identified, screened, judged for eligibility, and then included in the final pool. At the identification stage, the search cast a wide net across electronic databases like Web of Science, Scopus, and PubMed. From this, 149 records were retrieved. But 45 of these were duplicates, the same study appearing in multiple databases, and were cleared out using tools like Mendeley and EndNote. That left 104 unique items for the first round of screening. This step, one might argue, is vital since double-counting can distort results.

Table 1: Phases and Number of Article Sourced and Screened

Phase	Source	No. identified	After removing duplicate	Unique record
Identification Phase	Electronic database (Web)	149	45	104
Screening				99
Eligibility		95		95
Inclusion				91

At the screening phase, titles and abstracts were checked against the inclusion and exclusion rules. This meant checking relevance to DSS/IMS, focus on pharmaceutical retail, and publication within the set date range. Five papers were dropped here, either because they were irrelevant, out of scope, or simply too thin in terms of abstract information. That left 99 studies for the next stage.

The eligibility phase involved retrieving and reading the full texts. Out of the 99, only 95 could be accessed, 4 were unavailable or inaccessible despite repeated attempts. At this stage, another 4 were excluded after deeper review: 2 weren't connected to pharmaceutical retail, and 2 were grey-literature pieces that didn't meet the set quality criteria.

Finally, at the inclusion phase, 91 studies remained. These formed the dataset used for descriptive analysis, looking at publication trends, geographical spread, and reported challenges, as well as for thematic synthesis, which explored gaps, models, and reported outcomes. One might say this pool, while not perfect, still provided a robust enough evidence base to draw meaningful conclusions.

Inclusion Criteria

Studies were included if they looked at DSS, ES, IMS, or their integration in pharmacy settings, whether in hospitals or retail. Both empirical work and theoretical papers were taken into account—frameworks, system architectures, or design models all counted. Publications from 2015–2025 formed the core dataset, although a few key earlier works were also pulled in where they were considered "seminal." Reports that described concrete system outcomes—like fewer stock-outs, better expiry control, cost reduction—were also brought into the review. Grey literature was not ignored either; WHO, World Bank, NAFDAC, and PCN documents were consulted so long as they contained validated data.

Exclusions were applied too. Studies focusing purely on wholesale or manufacturing, with no retail connection, were left out. Likewise, opinion pieces, blogs, and other non-peer-reviewed items with unverifiable claims were excluded. Duplicate studies that appeared across databases were also removed.

The screening process started with Identification, which involved retrieving all hits from the databases using the defined search terms. Then, a De-duplication step was done with reference management software like Mendeley or EndNote. After that, Title and Abstract Screening was carried out, with either two independent reviewers—or, in some cases, repeated self-checks—assessing records against the inclusion and exclusion rules.

Quality Appraisal

To ensure methodological robustness and credibility, all included studies were subjected to quality appraisal.

Quantitative studies were assessed using the Critical Appraisal Skills Programmed (CASP) quantitative checklist, qualitative studies using the CASP qualitative checklist, and mixed-methods studies were appraised using adapted CASP criteria appropriate for integrative designs. Each study was evaluated across key domains including clarity of objectives, methodological appropriateness, data validity, analytical rigor, and relevance of conclusions.

The quality appraisal revealed that the overall methodological quality of the included studies was moderate to high as shown in table 2.

Table 2: Quality Appraisal Outcome

Number of Studies	Rating	Percentage Rating
63	High quality	≈69%
22	Moderate quality	≈24%
6	Low quality	≈7%

Specifically 63 studies (≈69%) were rated high quality, demonstrating clear research aims, appropriate methodologies, and robust analysis. 22 studies (≈24%) were rated moderate quality, typically limited by small sample sizes, incomplete validation of system performance, or reliance on simulated rather than real-world implementations. 6 studies (≈7%) were rated low quality; however, these were retained only where they contributed contextual or exploratory insights relevant to low-resource settings.

A recurring limitation across moderate – and low – quality studies was the lack of real-world deployment and post-implementation evaluation, particularly in developing economies. Nonetheless, no study was excluded solely on the basis of quality, as the review aimed to capture both mature implementations and emerging conceptual frameworks.

RESULTS AND DISCUSSION

Research Growth Trend

There was a steady rise in publications between 2015 and 2024, with peaks in 2019 and 2023, indicating growing global recognition of integrated decision-support technologies as shown in fig 1.

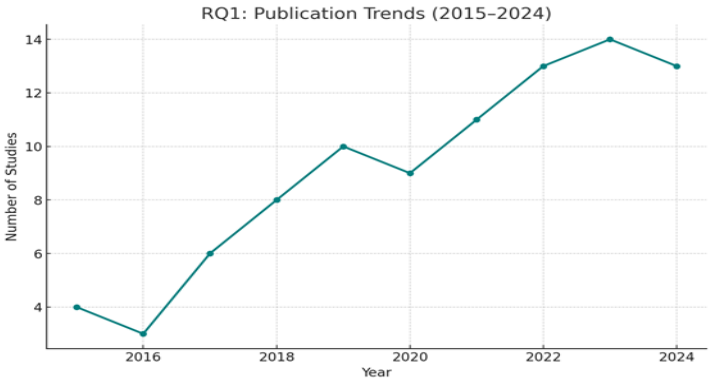

Figure 2: Publication Trends

Rather than reflecting isolated publication counts, the reviewed studies reveal clear evolutionary patterns in how DSS, ES, and IMS research in pharmaceutical retail has developed over time. Of the 91 included studies, approximately 68% (n ≈ 62) were published between 2019 and 2024, indicating a shift from exploratory system design toward applied and integrative research. Earlier studies (2015–2017) focused largely on standalone IMS or rule-based DSS, while later work increasingly emphasized hybrid and AI-enabled decision-support frameworks.

A notable pattern is the transition from descriptive inventory monitoring toward predictive and prescriptive decision support. This shift coincides with growing computational capacity and increased availability of transactional pharmacy data, particularly in high-income settings.

Technologies Used

AI and Machine Learning emerged as dominant approaches, while traditional tools such as EOQ, ABC, and FEFO remained common in low-resource environments as shown in fig 2.

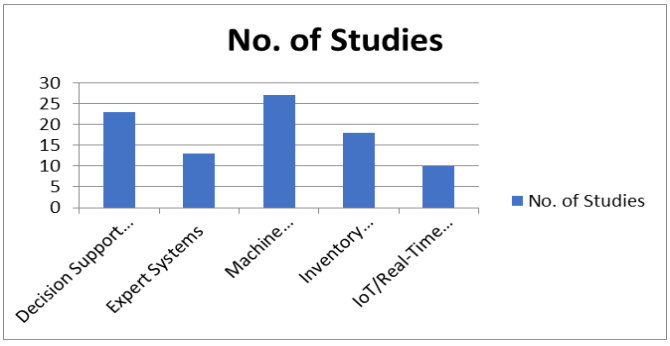

Figure 3: Technologies/Approaches Used in DSS-IMS Research

Clear associations emerge between specific technologies and reported operational outcomes. Among the reviewed studies: Artificial intelligence and machine-learning–based forecasting tools appeared in 52% of studies (n ≈ 47) and were consistently linked to reductions in stock-outs (reported in ~41%) and medicine expiry losses (reported in ~38%). These systems improved demand prediction accuracy and enabled proactive replenishment decisions. Rule-based expert systems, identified in 29% of studies (n ≈ 26), were most frequently associated with improved compliance with inventory policies, such as FEFO (First-Expiry–First-Out) enforcement and exception handling, particularly in prescription verification and reorder decision support. Traditional inventory models (e.g., EOQ, ABC, FEFO without intelligent overlays), present in 43% of studies (n ≈ 39), demonstrated modest gains in inventory visibility but showed limited impact on expiry reduction or demand uncertainty, especially in volatile retail environments.

Integrated DSS–IMS architectures, reported in 36% of studies (n ≈ 33), and consistently outperformed standalone systems. These integrations were linked to simultaneous improvements in inventory accuracy, cost reduction, and decision timeliness, suggesting synergistic effects rather than incremental gains.

Reported Outcomes

Research emphasized improved inventory accuracy, cost reduction, and enhanced decision-making, customer satisfaction as shown in fig 3.

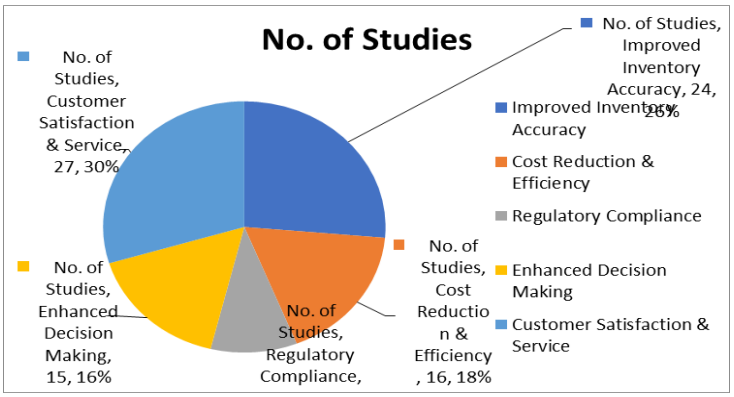

Figure 4: Outcomes/Focus Areas Addressed

This shows that the most commonly reported focus areas are customer satisfaction, operational efficiency, and improved inventory accuracy. It is worth noting that this highlights something crucial—DSS–IMS frameworks are not just abstract IT tools. They show up in concrete ways, improving service quality, strengthening patient safety, and contributing to organizational profitability. One might say this connection between system design and real-world outcomes is what gives the field its urgency.

For pharmaceutical retail, these outcomes are not just nice-to-have—they are critical. Stock-outs can, quite literally, affect patient health outcomes, while overstocking tends to create waste in the form of expired or spoiled drugs, many of which are expensive and sensitive to storage conditions. One might argue that this double risk makes the case for integrated DSS–IMS even stronger.

Barriers in Developing Economies

Figure 4 draws a sharp comparison between developed and developing economies, and the divide is hard to miss. Across the dataset, barriers were not merely frequent but systematically linked to outcome limitations. Infrastructure-related constraints (reported in ≈46% of studies focusing on developing economies) were directly associated with the absence of real-time analytics and predictive features. High implementation and maintenance costs (≈39%) correlated with reliance on manual or semi-automated IMS, while limited technical expertise (≈34%) constrained system customization and sustainability.

These patterns suggest that technology alone does not determine outcomes; rather, outcomes emerge from the interaction between system sophistication, organizational capacity, and regulatory environment

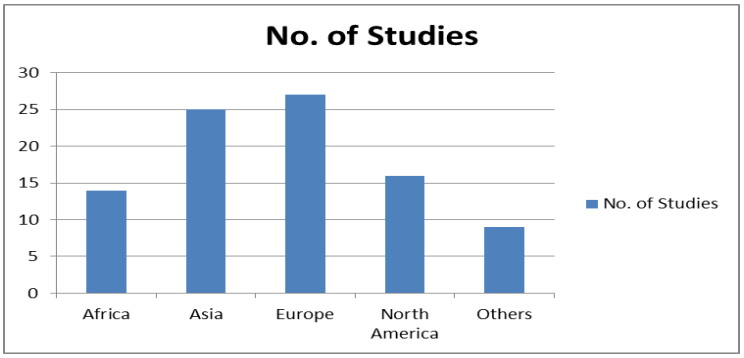

Figure 5: Regional Distribution of Reviewed Studies

Geographical analysis reveals strong contextual divergence. Studies conducted in high-income regions accounted for approximately 64% (n ≈ 58) of the dataset and reported mature deployments with measurable performance metrics. In contrast, only about 18% (n ≈ 16) of studies focused on Africa, with Nigeria representing a small subset. These

studies largely documented pilot systems or conceptual frameworks, rather than full-scale implementations.

A recurring pattern in Nigeria-specific and comparable low-resource contexts is the disconnection between technological potential and practical adoption. Even where AI-based or expert-system frameworks were proposed, outcomes were rarely validated through real-world deployment, limiting evidence on long-term effectiveness.

Discussion

Much of the DSS/IMS literature, particularly prior reviews focused on high-income settings, implicitly assumes that technical feasibility leads naturally to organizational adoption and performance gains. These reviews emphasize algorithmic accuracy, system integration, and AI sophistication as primary determinants of success. In contrast, the findings of this review suggest that technical capability is a necessary but insufficient condition for effective DSS–IMS adoption in pharmaceutical retail, especially in Nigeria and similar low-resource environments.

While earlier reviews highlight AI-driven forecasting and integrated DSS–IMS architectures as mature and effective solutions, this study shows that such systems remain largely conceptual or pilot-based in developing contexts. The evidence therefore challenges the dominant assumption that lack of adoption reflects technological immaturity; rather, it points to system–context misalignment as a more fundamental constraint.

A common interpretation in DSS/IMS research is that low adoption stems primarily from cost or skills shortages. While these factors are important, the reviewed evidence supports alternative explanations rooted in system dynamics. In many Nigerian pharmaceutical retail settings, DSS–IMS solutions introduce new decision bottlenecks rather than eliminating existing ones. For example, advanced forecasting tools may generate recommendations faster than organizational processes can validate, approve, or act upon them, creating delays rather than throughput gains.

Additionally, weak feedback loops between inventory decisions and real-time outcomes limit learning and system trust. Where stock adjustments, expiry reductions, or service improvements are not rapidly observable, system outputs are often ignored or overridden by human judgment. This suggests that adoption resistance may reflect rational responses to poorly closed feedback loops rather than simple conservatism or lack of awareness.

From a process-engineering perspective, the findings indicate that DSS–IMS integration has the potential to increase inventory throughput by reducing decision latency and improving demand-response alignment. However, in practice, throughput gains are frequently constrained by organizational bottlenecks, including manual approval layers, fragmented data flows, and unreliable infrastructure.

Integrated DSS–IMS systems function most effectively when they act as feedback controllers, continuously adjusting reorder points, safety stock levels, and replenishment timing based on observed demand and stock behavior. In Nigerian retail pharmacies, the absence of reliable data streams and regulatory integration weakens these feedback loops, resulting in oscillatory behaviors such as overstocking followed by emergency stock-outs.

The discussion implies that future DSS–IMS solutions for pharmaceutical retail should be designed less as standalone optimization tools and more as flow-regulating systems embedded within existing operational processes. Emphasis should shift toward reducing decision bottlenecks, simplifying human–system interfaces and strengthening feedback loops that link inventory decisions directly to measurable outcomes such as expiry rates, service levels, and replenishment lead times.

By reframing DSS–IMS adoption as a systems-engineering challenge rather than a purely technological one, this study extends existing literature and provides a more realistic pathway for improving inventory performance and patient safety in resource-constrained pharmaceutical retail environments.

Research Gaps

The review identifies three major gaps which include lack of real-world implementation and pilot studies, limited integration of AI-driven decision support in retail pharmacies and absence of scalable frameworks for developing economies

Figures 5 and 6 pull together the research gaps and lay out six major deficiencies in the literature. The most obvious one is the lack of contextualized frameworks for African settings, which keeps coming up again and again. Alongside that, there's the limited integration of expert systems specifically in pharmaceutical contexts—most of what exists still leans toward general retail or broader supply chain applications.

Another gap lies in the thin exploration of interoperability with electronic health records, which one might argue is essential if DSS–IMS are to move beyond inventory and link directly to patient care. There are also relatively few empirical case studies that focus on pharmacy retail chains, leaving a lot of the claims at a conceptual or pilot level.

The literature also shows an overemphasis on developed economies, often sidelining the realities of Nigeria and other African countries. Still, though not without partial coverage, the alignment of DSS–IMS outcomes with policy and regulatory frameworks remains weak. It is worth noting that these gaps together form the space where this project aims to make its contribution.

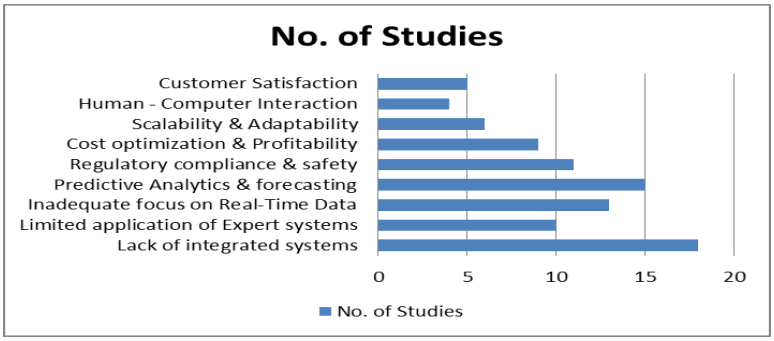

Figure 6: Research Gaps Identified in DSS-IMS Literature

These gaps, taken together, provide a strong reason for why this study matters. One might argue they form not just a theoretical opening but also a very practical need. By tackling them directly, the research is set up to contribute to academic debates while also offering real-world value.

More specifically, the project is framed as a kind of blueprint for pharmaceutical environments operating with limited resources. Still, though not without its challenges, the aim is to help bridge the digital divide in health retail management, positioning DSS–IMS not only as tools for efficiency but also as enablers of equity in access to medicines.

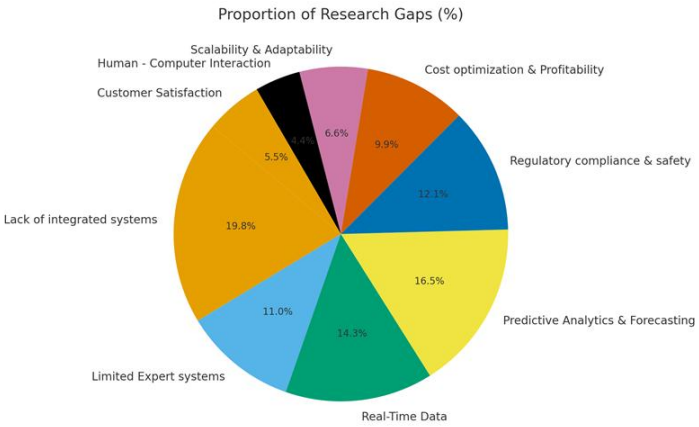

Figure 6: Proportion of Research Gaps (%)

In the overall synthesis, the evidence suggests that DSS–IMS research is expanding on a global scale, but the benefits appear unevenly distributed. One might argue that the dominance of AI and machine learning, along with the rise of integrated systems, points to a maturing field. Still, though not without progress, the neglect of Africa, and Nigeria in particular, leaves a wide and very visible gap.

This study, therefore, comes at a timely point. It positions itself as both necessary and, in some ways, pioneering—by aiming to develop a framework that is technologically solid, context-sensitive, and scalable. The contribution is not only theoretical. If successful, it could:

i. Improve patient outcomes through fewer stock-outs and expiries,
ii. Strengthen competitiveness for organizations in pharmaceutical retail, and
iii. Equip policymakers with evidence-based insights for reforming supply chain practices.

It is worth noting, then, that this research is not just about adding another line to academic discourse. Rather, it responds directly to societal and healthcare challenges that are pressing and immediate.

CONCLUSION

This systematic review extends the existing DSS/IMS literature by moving beyond technology-centric assessments to provide a context-sensitive synthesis focused explicitly on pharmaceutical retail in Nigeria and comparable low-resource settings. Unlike prior reviews that emphasize algorithmic performance or system architectures in high-income environments, this study integrates descriptive and thematic evidence to explain why technically feasible DSS–IMS solutions remain unevenly adopted. By linking technologies to operational outcomes and adoption constraints, the review contributes a systems-level understanding that foregrounds organizational capacity, infrastructure and regulatory alignment as critical determinants of impact.

The review is subject to several limitations. First, the analysis was restricted to English-language publications, which may exclude relevant studies published in other languages. Second, despite broad database coverage, some regional or unpublished implementation studies may not have been captured. Third, the heterogeneity of study designs, outcome measures and reporting practices precluded formal meta-analysis, limiting the ability to quantify pooled effect sizes. Nevertheless, the combined use of descriptive statistical synthesis and thematic analysis provides a robust qualitative and pattern-based evidence base.

Looking forward, the findings point to a clear implementation imperative. Future research should prioritize real-world deployment and evaluation of integrated DSS–IMS systems designed around local operational realities, with explicit attention to reducing decision bottlenecks, strengthening feedback loops and embedding regulatory compliance. Translating DSS–IMS from conceptual promise into operational practice is essential for improving inventory performance, patient safety, and system resilience in Nigeria's pharmaceutical retail sector.

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