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Research Article

Counting the Cost of Supply Errors: An Analysis of Product Fulfilment Failures in Public Healthcare

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ABSTRACT

Background: Incomplete product fulfilment is a persistent operational challenge in pharmaceutical supply chains, producing discrepancies between ordered and supplied commodities. These failures including under-supply, over-supply, wrong commodity delivery, and invoice inconsistencies impose direct and indirect economic costs on health systems and, where they result in stock-outs, carry consequences that extend to patient access and health equity. **Objective:** To assess the economic implications of incomplete product fulfilment in a public pharmaceutical supply chain using routine supply error records. **Methods:** A retrospective descriptive analysis was conducted using supply error records documented between December 2025 and May 2026 at the Plateau State Drugs and Medical Commodities Management Agency (PS-DMCMA), Jos, Nigeria. Data were extracted from a centralised, institutionally maintained supply error tracker and analysed for frequency, error typology, and monetary value of fulfilment discrepancies at transfer price. **Results:** More than 21 discrete supply error incidents were documented across at least nine health facilities. Under-supply was the predominant error type, with a cumulative transfer price value of ₦2,945,457.60, accounting for approximately 91% of the combined discrepancy total of ₦3,235,407.10. The highest monthly under-supply value was recorded in January 2026 (₦1,132,203.10). Primary documented causes were pick-and-pack errors, confirmation errors, and loading errors. **Conclusion:** Supply fulfilment errors impose substantial and quantifiable economic costs on a public pharmaceutical supply chain.

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These costs are compounded by indirect burdens including administrative workload, emergency redistribution, and downstream stockout effects that are not captured in transfer price valuations. Dual-verification protocols, digital proof-of-delivery, and structured staff training are recommended as priority interventions.

INTRODUCTION

Access to essential medicines is a fundamental prerequisite for effective healthcare delivery, particularly in resource-limited settings. The World Health Organisation (WHO) Regional Office for Africa has reported that active shortages of essential health products affect the majority of African countries, with some facilities experiencing temporary service closures due to stockouts (WHO Regional Office for Africa, 2025). For populations that rely exclusively on public facilities for care, these supply failures carry profound clinical and economic consequences.

Within pharmaceutical supply chains, product fulfilment defined as the accurate, complete, and timely delivery of ordered commodities to requesting facilities is a critical operational output. Failures at this stage produce discrepancies between what facilities requisition and what they actually receive. These may manifest as under-supply, over-supply, wrong commodity delivery, or invoice inconsistencies, any of which can disrupt facility-level operations and patient care (Olu-tuase et al., 2022).

Under-supply is of particular concern, as it directly generates gaps in product availability at the point of care. A study using causal identification methods in Uganda demonstrated that public sector stockouts raised private-sector antimalarial drug prices by 35% and reduced the likelihood that children received medicine by 61%, illustrating how supply chain failures within public agencies rapidly translate into economic and equity consequences for patients (Fitzpatrick, 2022). In the Nigerian context, poor logistics practices, weak in-country logistician support, and inadequate supply chain management systems have been specifically identified as drivers of distribution underperformance (Chukwu et al., 2018).

Over-supply also carries economic implications through tied-up capital, expiry-related wastage, and the

administrative overhead of retrieval, re-invoicing, and redistribution. Mabizela et al. (2023) documented, in a retrospective study of public facilities in South Africa, that overstocking and stockouts frequently co-occur within the same supply system and that overstocking significantly predicts both expiry wastage and redistribution cost (Mabizela et al., 2023).

Health product supply chains in developing countries are recognised to be especially vulnerable to distribution-tier failures, including inadequate logistics management capacity and insufficient performance monitoring (Yadav, 2015). Privett and Gonsalvez (2014) identified vulnerable warehouse inventory and inopportune order management as two of the ten most critical challenges facing health supply chains globally (Privett & Gonsalvez, 2014).

The Plateau State Drugs and Medical Commodities Management Agency (PS-DMCMA) is the central procurement and distribution hub for medicines and medical commodities to Hospitals Management Board (HMB)-managed facilities and primary healthcare centres across Plateau State, Nigeria. Beginning in the latter quarter of 2025, PS-DMCMA operationalised a structured supply error tracking system as a quality improvement initiative. This paper presents a retrospective analysis of data generated by that system over a six-month period (December 2025 to May 2026), with the objectives of characterising the frequency, typology, and direct economic value of fulfilment discrepancies, and situating findings within the broader supply chain literature.

2. Background and Literature Review

2.1 Pharmaceutical Distribution Errors: Internal Process Failures

Pharmaceutical supply chain risk encompasses a broad range of operational failures that impede the delivery of medicines in the right quantity, quality, place, and time. A systematic review by Jaberidoost et al. (2013) found that the majority of risks in pharmaceutical supply chains are internal in origin arising from process, people, and functional mismanagement and are amenable to mitigation through structured management strategies (Jaberidoost et al., 2013). At the distribution tier, the picking, packing, and dispatch stages are



particularly error-prone given their dependence on manual processes and human verification.

Inventory record inaccuracy (IRI) defined as a discrepancy between the quantity recorded in a management system and the quantity physically available is a well-documented antecedent of fulfilment failure. DeHoratius and Raman (2008), in an empirical analysis of nearly 370,000 inventory records across 37 stores, found that 65% were inaccurate, and identified complexity of the distribution environment and inadequate auditing practices as key drivers of IRI (DeHoratius & Raman, 2008). In manual pharmaceutical warehouse systems, analogous dynamics make pick-and-pack and confirmation errors structurally likely unless specific verification controls are in place.

The WHO Good Distribution Practices for Pharmaceutical Products explicitly identify outgoing goods verification, dispatch documentation, and quality systems at the warehouse level as critical checkpoints in distribution quality assurance (World Health Organization, 2010). Failures at these checkpoints whether through omission, inaccuracy, or inadequate confirmation directly produce fulfilment discrepancies at the receiving facility.

2.2 Economic and Health Consequences of Supply Chain Failures

The economic and health consequences of supply chain failures extend beyond the direct value of discrepant commodities. Fitzpatrick (2022), in a causal analysis using difference-in-differences methods applied to four data sources in Uganda, found that public sector stockouts increased private-sector antimalarial prices by 35%, reduced care-seeking among poorer and less-educated patients, and reduced the probability that children received medicine by 61% (Fitzpatrick, 2022). These findings demonstrate that supply failures at the point of distribution generate cascading economic consequences far in excess of the commodity value of the shortfall itself.

A scoping review by Aryani et al. (2026), reviewed existing medicine supply chain management models and identified inadequate distribution processes, poor logistics information systems, and human resource constraints as the dominant determinants of medicine

stockouts in primary care settings globally (Aryani et al., 2026). These structural determinants directly underlie the operational error types documented at PS-DMCMA.

2.3 Pharmaceutical Supply Chain Challenges in Nigeria

A scoping review by Olutuase et al. (2022), synthesised evidence from studies published between 2005 and 2020 and identified persistent challenges across all stages of the pharmaceutical supply chain in Nigeria, including distribution inefficiencies and poor logistics performance as key contributors to medicine stockouts (Olutuase et al., 2022). Chukwu et al. (2018) specifically identified poor logistics and supply chain management practices, weak regulation, and the absence of in-country logistician support as the principal indicators of SCM underperformance in Nigeria a structural context in which picking, packing, and confirmation errors are more likely to occur and less likely to be detected (Chukwu et al., 2018).

2.4 Supply Chain Performance in Sub-Saharan Africa

Vledder et al. (2019), in a large-scale randomised controlled trial conducted across 439 health facilities and 24 districts in Zambia, demonstrated that moving from a traditional three-tier distribution model to a direct cross-docking arrangement reduced the frequency of stockouts for first-line paediatric malaria medicines from 47.9% to 13.3%, and reduced the days of stockout per quarter from 27 to 5 (Vledder et al., 2019). This evidence establishes that the structure and processes of the distribution system not procurement alone are the primary determinants of product availability at health facilities.

A systematic review by Seidman and Atun (2017), confirmed that supply chain change interventions in LMICs generate measurable improvements in medicine availability and system efficiency (Seidman & Atun, 2017). This reinforces the value of process-level interventions such as the error-tracking and quality improvement system operationalised at PS-DMCMA as drivers of supply chain performance.

METHODS



3.1 Study Design

This study employed a retrospective descriptive design to analyse supply error records generated by PS-DMCMA between December 2025 and May 2026. Descriptive analysis was used to characterise the frequency, typology, and monetary value of documented fulfilment discrepancies without testing causal hypotheses, consistent with the objectives of routine healthcare operational data studies.

3.2 Study Setting

PS-DMCMA is a government parastatal under the Plateau State Ministry of Health responsible for the procurement, warehousing, and distribution of medicines and medical commodities to a network of health facilities across Plateau State, Nigeria. This network comprises A state specialist hospital, 17 HMB-managed secondary health facilities and multiple primary healthcare centres across the state's 17 local government areas. Distribution is conducted through a scheduled Last Mile Distribution (LMD) system, with commodities delivered directly to facilities following facility-level requisitioning.

The PS-DMCMA supply error tracking system functions as a centralised register for complaints and discrepancies communicated by facility pharmacy and laboratory staff following each LMD cycle. It documents the nature, monetary value, cause attribution, and resolution status of each reported discrepancy.

3.3 Data Collection

Data were extracted from the PS-DMCMA Supply Error Tracker for December 2025 to May 2026 the first six months of structured, value-documented error tracking at the agency. Records from August to October 2025 were available but lacked systematic value documentation and were excluded from the primary economic analysis, though referenced contextually. Variables extracted included: date of complaint, facility name, error type, discrepancy details, probable cause as attributed by agency staff, monetary value at transfer price (₦), corrective action taken, resolution status, and resolution time.

3.4 Data Analysis

Data were organised and analysed descriptively. Monthly and cumulative totals were computed for over-supply and under-supply values. Incident frequencies were tabulated by month and facility. Error type frequencies were summarised from documented probable cause entries. Economic implications were assessed using the direct monetary value of supply discrepancies at transfer price the price at which commodities are invoiced from PS-DMCMA to receiving facilities. Indirect costs were not included in primary calculations due to the absence of systematically recorded data but are addressed in the discussion.

3.5 Ethical Considerations

This study is based on aggregated operational data generated in the routine course of public supply chain management. No patient-level data were used. Facility-level identifiers are reported as they appear in official agency records. As a retrospective analysis of programmatic data, formal ethical review was not required; data were handled in accordance with principles of confidentiality and institutional data governance.

RESULTS

4.1 Overview of Supply Errors Documented

A total of more than 28 discrete supply error incidents were documented across the six-month study period, spanning at least nine unique health facilities. Incident volume increased over the period, with the highest frequency recorded in April/May 2026, consistent with progressive systematisation of error reporting. March 2026 recorded no value-documented incidents, though facility-level complaints were noted in the tracker. Under-supply was the predominant error type across all months, accounting for the majority of both incident frequency and aggregate economic value.

4.2 Monthly Distribution of Fulfilment Discrepancies

Table 1 presents the monthly distribution of incidents and associated economic values. The cumulative under-supply value totalled ₦2,945,457.60, and the cumulative over-supply value totalled ₦289,949.50. The combined direct economic value of all documented



fulfilment discrepancies exceeded ₦3.2 million at transfer prices.

Table 1: Monthly Distribution of Supply Error Incidents and Associated Economic Values (December 2025 – May 2026)

Month	n	Over-Supply Value (₦)	Under-Supply Value (₦)	Total Discrepancy Value (₦)
December 2025	2	₦115,737.00	₦413,116.00	₦528,853.00
January 2026	4	₦21,504.00	₦1,132,203.10	₦1,153,707.10
February 2026	1	—	₦26,880.00	₦26,880.00
March 2026	0	—	—	—
April/May 2026	14+	₦152,708.50	₦1,373,258.50	₦1,525,967.00
Total	21+	₦289,949.50	₦2,945,457.60	₦3,235,407.10

The highest monthly under-supply value was recorded in January 2026 at ₦1,132,203.10. A single incident at General Hospital Barkin Ladi involving non-supply of Metronidazole (1,000 tablets × 4 Tins) and Paracetamol (1,000 tablets × 90 tins) accounted for ₦813,337.10 of

this total, the highest single-incident value in the dataset.

4.3 Nature and Typology of Fulfilment Errors

Seven error types were documented across the study period, summarised in Table 2.

Table 2: Typology of Documented Fulfilment Errors (December 2025 – May 2026)

Error Type	Description	Frequency	Comment
Pick and Pack Error	Incorrect item or quantity selected from warehouse shelving, or items omitted during packaging	21	High
Confirmation Error	Failure to verify item identity and quantity against the pick list before dispatch	14	High
Loading Error	Correctly packed items omitted during loading onto the delivery vehicle	6	Moderate
Requisition Error	Inaccuracies in originating order documentation from the requesting facility	3	Moderate
Short-Dated Product	Supply of commodities near expiry, resulting in rejection at facility level	1	low
Wrong Commodity	Supply of incorrect product variant or specification (e.g. wrong dosage strength)	1	Low
Invoice / POD Error	Discrepancy between proof-of-delivery documentation and actual quantities supplied	4	Moderate

Pick-and-pack errors and confirmation errors were the most frequently attributed causes across all months. These failure modes frequently appeared as co-attributed causes in the same incident, suggesting a sequential pattern: an item is incorrectly selected or omitted at the picking stage, and this error is not detected at the subsequent confirmation stage before dispatch. Loading errors were documented in at least one incident involving surgical gloves at General Hospital Pankshin. Wrong commodity errors including supply

of Artesunate injection 60mg instead of 120mg carry clinical implications beyond the economic. Short-dated product rejection at General Hospital Mabudi in April 2026 constituted a supply failure equivalent in operational consequence to non-supply for the receiving facility.

4.4 Facility-Level Distribution of Incidents

Table 3 identifies the eight facilities with value-documented supply error incidents and the nature of errors recorded.

Table 3: Facility-Level Distribution of Documented Supply Error Incidents (December 2025 – May 2026)



Facility	Month(s)	Nature of Error
GH Tunkus	December 2025; April/May 2026	Excess supply, under-supply, wrong commodity, requisition error
GH Shendam	January 2026; April/May 2026	Under-supply, excess supply
GH Barkin Ladi	January 2026	Under-supply (highest single-incident value: ₦813,337)
CH Bokkos	January 2026; April/May 2026	Under-supply, invoice/POD discrepancy
GH Pankshin	January 2026; April/May 2026	Under-supply, loading error (surgical gloves)
GH Mabudi	January 2026; April/May 2026	Under-supply, short-dated product rejection (Amlodipine)
GH Kwal	December 2025	Excess supply, under-supply
CHC Dadinkowa	February 2026	Item not supplied

GH = General Hospital; CH = Cottage Hospital; CHC = Comprehensive Health Centre

GH Tunkus and GH Mabudi were the only facilities with documented incidents across multiple months. GH Barkin Ladi recorded the highest single-month under-supply value. The extension of error documentation to laboratory units in April and May 2026 indicates a maturing of the tracking system beyond pharmaceutical supply to encompass laboratory commodity fulfilment.

4.5 Resolution and Corrective Actions

Documented corrective actions included: escalation to senior agency management; supply of balance quantities at the next scheduled LMD cycle; retrieval of over-supplied goods; reversal and reissuance of affected invoices; and emergency supply in clinically urgent cases. Resolution times ranged from same-day resolution to over three weeks, with January 2026 incidents showing the longest pending periods. Invoice reversal requiring coordinated action across procurement, finance, and logistics functions — was required in at least five documented incidents.

DISCUSSION

5.1 Economic Significance of Fulfilment Discrepancies

The total direct economic value of documented supply discrepancies at PS-DMCMA over six months exceeded ₦3.2 million at transfer prices, with under-supply accounting for approximately 91% of this total. The significance of these figures must be contextualised carefully: transfer prices represent the cost to the distributing agency and likely understate the full economic burden. Facilities experiencing under-supply

may need to procure shortfall items through emergency channels at higher market prices. Fitzpatrick (2022) demonstrated empirically that public sector supply failures generate a price premium of 35% in private markets and reduce access among the most vulnerable populations (Fitzpatrick, 2022). These downstream economic effects are not captured in the transfer price values reported here but are the direct consequence of the distribution failures documented.

The economic estimates in this study are necessarily conservative for additional reasons: incidents from August to October 2025 were excluded for incomplete value documentation, and some April and May 2026 incidents remained unresolved at the time of review. The true rate of fulfilment failure over the full period is therefore likely higher than this dataset reflects.

5.2 Process Determinants of Fulfilment Failure

The predominance of pick-and-pack and confirmation errors as probable causes is consistent with the literature on internal pharmaceutical supply chain failures (Jaberidoost et al., 2013). In the absence of automated verification systems, reliance on manual checking creates vulnerability to error under time pressure or staffing constraints. The WHO Good Distribution Practices explicitly identify outgoing goods verification as a critical quality control step whose absence is associated with supply inaccuracies (World Health Organization, 2010).

The sequential co-occurrence of pick-and-pack and confirmation errors where an error at picking was not caught at confirmation reflects a systems failure rather than individual error alone. DeHoratius and Raman (2008) showed empirically that inventory inaccuracy is driven by the complexity of the distribution



environment and the absence of auditing controls, both of which are characteristic of manual multi-facility LMD systems (DeHoratius & Raman, 2008). Aryani et al. (2026) similarly identified poor logistics information systems and inadequate human resource capacity as structural drivers of supply chain failures in primary care settings (Aryani et al., 2026).

Loading errors highlight a third distinct failure point: the transition from packed order to loaded vehicle. In a multi-facility LMD context, items intended for one facility may be omitted during loading or placed on the wrong consignment, particularly where loading is performed under time pressure without independent manifest verification.

5.3 Indirect Costs and Broader Economic Burden

The direct economic values documented here represent only the most immediately quantifiable component of the total burden. Complaint resolution and redistribution impose administrative demands on agency staff. A conservative estimate of two to three person-hours per incident across 21 or more incidents in six months suggests a minimum of 42 to 63 staff-hours consumed by error resolution a direct opportunity cost against productive supply chain functions. Chukwu et al. (2018) documented that the absence of validated monitoring systems and weak logistician support in Nigeria amplifies these costs by reducing the speed and accuracy of error detection and resolution (Chukwu et al., 2018).

Seidman and Atun (2017) showed that supply chain improvement programmes in LMICs generate measurable efficiency gains, implying that persistent fulfilment failures without systematic correction produce avoidable expenditure over time (Seidman & Atun, 2017). Invoice discrepancies that remain unresolved introduce accounts receivable distortions in facility financial records and may complicate future procurement cycles. The systemic consequences of repeated under-supply stock depletion, service rationing, and potential patient harm cannot be fully quantified from routine operational data but are well-documented in the supply chain literature.

5.4 Implications for Supply Chain Quality Improvement

The findings support several evidence-based interventions. First, dual-verification protocols at the picking and confirmation stages directly address the most frequently documented failure mode. Second, digital proof-of-delivery tools, supported by mobile technology, would provide real-time confirmation of delivered quantities and reduce invoice-to-delivery mismatches. These measures are consistent with the quality checkpoints prescribed in the WHO Good Distribution Practices (World Health Organization, 2010). Third, structured staff training on picking accuracy, manifest verification, and complaint escalation addresses the human factors dimension of documented errors.

Privett and Gonsalvez (2014) identified workforce capacity in supply chain management as among the most critical global health supply chain challenges (Privett & Gonsalvez, 2014). Vledder et al. (2019) demonstrated through a large-scale RCT that structural reform of the distribution model moving to direct, cross-docking arrangements can dramatically reduce stockout frequency (Vledder et al., 2019). A fourth, longer-term intervention is therefore a periodic review of the LMD model at PS-DMCMA to assess whether modifications to route structure, vehicle deployment, or facility groupings could reduce the loading error risk associated with multi-destination deliveries.

The institutionalisation of the PS-DMCMA error-tracking system with regular review and feedback loops to warehouse staff would convert an operational register into a continuous quality improvement engine. The establishment of standardised fulfilment performance indicators for public pharmaceutical supply chains in Nigeria would support comparative monitoring across states and align with the WHO Africa Regional Strategy on Market Shaping and Supply Chain for Essential Health Products (WHO Regional Office for Africa, 2025).

5.5 Study Limitations

Several limitations must be acknowledged. First, this study is restricted to a single supply agency over a six-month period; findings may not be directly generalisable to other agencies, though they are consistent with documented regional patterns. Second, economic values reflect transfer prices rather than replacement or



market costs; the true burden on receiving facilities may be substantially higher. Third, the analysis does not capture indirect costs including administrative time, emergency transport, or patient outcomes. Fourth, the March 2026 data gap and incomplete value documentation for some incidents suggest the tracker is still maturing as a data instrument. Fifth, probable cause attribution reflects staff documentation at the time of complaint, not a formal root cause analysis.

Despite these limitations, this study contributes original empirical data on the direct economic quantification of pharmaceutical supply fulfilment errors in a subnational public supply chain agency in Nigeria a context in which such data are rarely systematically documented or published.

CONCLUSION

Incomplete product fulfilment represents a quantifiable and economically significant challenge in public pharmaceutical supply chains. Over a six-month period at PS-DMCMA, supply discrepancies with a combined direct value exceeding ₦3.2 million at transfer prices were documented, with under-supply accounting for approximately 91% of the economic burden. Pick-and-pack and confirmation failures at the warehouse and dispatch stage were the most frequently attributed proximate causes, consistent with the literature on internal process failures in pharmaceutical distribution.

The direct economic estimates reported here understate the true burden: indirect costs emergency redistribution, administrative workload, invoice processing, and downstream stockout effects including price spillovers to private markets and reduced access among vulnerable patients are not captured. Future research should quantify these dimensions through activity-based costing approaches and should examine clinical outcomes associated with commodity gaps at affected facilities.

The PS-DMCMA supply error tracking system provides a replicable and low-cost model for quality improvement in subnational pharmaceutical supply chains across Nigeria. Routine documentation, economic quantification, and systematic review of fulfilment discrepancies constitute a foundational evidence base for managerial decisions, operational accountability, and the strengthening of medicine supply

reliability at public health facilities a priority that is consistent with the broader agenda for health supply chain reform in sub-Saharan Africa (Yadav, 2015).

Declarations

Funding:

No external funding was received. Data were generated through routine institutional operations of PS-DMCMA.

Conflicts of Interest:

The author declares no conflicts of interest. The author is a staff member of PS-DMCMA; the data used are operational records of the institution.

Data Availability: Supply error tracker data may be made available upon reasonable request subject to institutional approval from PS-DMCMA, Plateau State, Nigeria.

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