Challenges of vaccine storage, transportation, and distribution in southeast Nigeria: A Narrative Review

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Abstract
Safeguarding vaccine potency requires flawless cold chain execution, a task that remains incredibly difficult in resource-constrained environments. This narrative review evaluates the systemic bottlenecks plaguing vaccine storage, transportation, and distribution networks across Southeast Nigeria. We searched PubMed, African Journals OnLine (AJOL), and Google Scholar for studies, regional audits, and institutional reports published up to December 2025. Extracted data were synthesized to cross-examine physical infrastructure against the regional human resource capacity. The data reveals a stark gap between logistics infrastructure and operational realities. Over 30% of local primary healthcare centers lack working refrigerators, leaving them heavily reliant on ice boxes and makeshift transit routines. This physical deficit is aggravated by severe power grid instability, a critical shortage of climate-controlled vehicles, and worsening regional security threats in states like Anambra and Imo. On the human capital side, nearly 42% of active vaccinators cannot identify safe vaccine storage temperature ranges, largely because regular, structured professional training remains virtually nonexistent.
The supply chain of vaccine in Southeast Nigeria is compromised by both infrastructure gaps and a lack of staff training. Revitalizing this system requires a shift toward decentralized solar refrigeration, institutionalized training regimens, and the deployment of real-time digital monitoring platforms.

Keywords: Vaccine, cold chain, transport, storage, supply chain, southeast, Nigeria

Introduction

Vaccines play a critical role in preventing infectious diseases worldwide. However, their efficacy depends heavily on maintaining appropriate conditions during storage, transportation, and distribution (Dairo and Osizimete, 2016). Logistics, particularly in the cold chain, pose significant threats to vaccine potency in Nigeria (Olutuase et al., 2022). The southeast region of Nigeria faces unique logistical barriers due to infrastructural deficits, insecurity, difficult terrain, inadequate staff knowledge, and inconsistent government support. The role of skilled personnel in maintaining the vaccine cold chain is crucial and cannot be overstated. However, several studies consistently show that health workers in many parts of Nigeria lack the necessary training and knowledge to manage vaccines effectively. In a nationwide assessment, Ojo et al. (2019a) reported that nearly 42% of vaccinators were unable to identify the correct temperature range for vaccine storage. Alarmingly, only 38% of the respondents had received formal training within the last two years. A nationwide audit by the National Primary Health Care Development Agency (NPHCDA, 2022) indicated that more than 30% of primary health care (PHC) facilities lacked functional refrigerator. In some facilities, cold boxes were used as the sole means of storage, even for extended periods, which goes against best practices.

Chukwu et al. (2018) assessed vaccine transport mechanisms across five Nigerian states and found irregular delivery schedules and severe vehicle shortages. Many LGAs lacked dedicated vehicles for vaccine transportation, relying instead on general-purpose or borrowed vehicles, often without cold boxes or ice packs. Most of the LGAs exceeded the WHO-recommended maximum of 30-day interval between deliveries. Even when vaccines are available and transport is arranged, distribution can be severely affected by insecurity and bureaucratic delays. In conflict-prone areas of the South-East, such as parts of Anambra and Imo States, security threats caused regular disruptions to routine vaccination activities.

These challenges undermine routine immunization coverage and contribute to the outbreaks of diseases preventable by vaccine. Understanding these logistical gaps and proposing evidence-based interventions is essential for strengthening vaccine supply chains and ensuring the delivery of potent vaccines to all communities. Despite global efforts to improve vaccine delivery systems, Nigeria continues to experience challenges that compromise vaccine quality and accessibility. In the Southeast region, storage equipment breakdowns, poor transportation infrastructure, variations in temperature, and inadequate training of health workers have been reported. There is limited empirical evidence that holistically examines these issues in this region. This gap in research hinders the formulation of targeted strategies to enhance vaccine logistics. This study employed narrative review to address the challenges of vaccine storage, transportation, and distribution in southeast Nigeria.

Methods

In order to articulate and untangle the overlapping factors affecting vaccine delivery in Southeast Nigeria, this study utilizes a structured narrative review framework. This methodology provides a holistic approach to synthesizing empirical research data, policy frameworks, and national health reports.

Search and retrieval protocol: We conducted electronic literature searches across PubMed, African Journals Online (AJOL), and Google Scholar for studies published up to December 2025. Our search strategy utilized paired keyword strings designed to capture both geographic and operational nuances: ("vaccine supply chain" OR "cold chain integrity") AND ("Primary Health Care" OR "health workforce capacity") AND ("Southeast Nigeria" OR "regional logistics bottlenecks").

Sifting and selection criteria: We limited our scope to English-language papers analyzing the functional inputs. To qualify for inclusion, studies had to offer direct insights into Nigerian logistics, with priority given to data targeting the unique socio-topographical landscape of the Southeast. We excluded clinical vaccine efficacy trials, focusing exclusively on operational supply chain dynamics. National audit datasets from agencies like the NPHCDA and UNICEF were integrated to ground peer-reviewed findings in current policy realities.

Data analysis: Rather than treating logistics indicators in isolation, we categorized findings into four core structural themes: storage capacity, transit vulnerabilities, personnel skills, and information management systems. These categories were evaluated using the WHO Health Systems Framework alongside General Systems Theory to track how minor friction points in localized clinics escalate into widespread, systemic vaccine failures.

Results and discussion

The conceptual framework of logistical inputs in vaccine services

The conceptual framework posits that those logistical inputs, including transportation access, cold chain infrastructure, human resource capacity, and data management systems, are key determinants of vaccine potency and availability. These, in turn, are hypothesized to influence vaccination program outcomes. Transportation infrastructure is critical in ensuring timely delivery, especially in rural or hard-to-reach wards; poor road access and unreliable vehicles can hinder distribution to peripheral health centers (Ojo et al., 2019b; Ayowole, 2025; Sarley et al., 2017). The functionality of cold chain equipment and availability of power supply are determinants of effective vaccine handling and storage. A significant deficit of approximately 3,225 units exists between current and required cold chain equipment in Nigeria (National Strategic Cold Store data). Reorganization of the supply chain, including solar refrigerators and maintenance regimes, could reduce storage shortfalls significantly (Ayowole, 2025; Sarley et al., 2017).

Human resources and training influence vaccine handling and monitoring practices. Studies from Ife, Kwara, and Kaduna State revealed substantial gaps: up to 29% of vaccinators had no training, and only 3.8% demonstrated high competence (Ojo et al., 2019a; Adeyemi et al., 2019). Data management and Logistic Management Information System (LMIS) use, such as Nigeria's integration of vaccine logistics data into District Health Information Software-2 (DHIS2) used for vaccine data management, strengthen stock visibility and decision-making. This integration raised cold chain equipment functionality from below 50% to nearly 90% by 2022 (DHIS2 Nigeria report). Together, these variables shape whether vaccines maintain their potency and are available where needed.

Two major theoretical models guide the framework of this research: the Health Systems Framework developed by the World Health Organization (WHO) and General Systems Theory, including elements of System Dynamics. These theories are relevant in explaining how different components of vaccine logistics (storage, transportation, and distribution) interact and contribute to the overall effectiveness of vaccination programs in South-East Nigeria.

Health systems framework (WHO building-blocks model)

The Health Systems Framework postulated by the WHO is widely used to understand and analyses the performance of health systems. It identifies six critical building blocks: service delivery, medical products and technologies, health financing, and leadership/governance (WHO, 2007). For this study, the most relevant building blocks include medical products and technologies (which covers cold chain equipment), the health workforce (which includes human resource capacity and training), logistics and data management systems.

Challenges with cold chain infrastructure, such as frequent power outages, lack of functional refrigerators, and insufficient ice packs, directly reflect failures in the "medical products and technologies" block. Similarly, inadequate training, low staffing levels, and poor supervision mirror weaknesses in the "health workforce" component. These systemic issues, as identified by studies conducted in Nigeria and other low- and middle-income countries (LMICs), have shown that poor infrastructure and management systems contribute to reduced vaccine potency, increased wastage, and low immunization coverage (Agyepong et al., 2017; Akande et al., 2020).

General systems theory and system dynamics

General Systems Theory (von Bertalanffy, 1968) provides another useful lens for analyzing vaccine logistics. It views organizations and processes as complex, interrelated systems, in which a failure in one subsystem can affect the entire chain. This theory is helpful in modelling vaccine logistics because it encourages a holistic approach to problem-solving. For example, a failure in the data reporting system (such as poor stock visibility or delays in vaccine requisition) can lead to stockouts, which affects service delivery and vaccination rates. Systems Dynamics, a related theory, focuses on the behavior of complex systems over time and incorporates feedback loops and time delays. This approach is essential in vaccine logistics for modelling how delays in transportation, staff turnover, or malfunctioning cold chain equipment can affect vaccine availability. Studies applying system dynamics in health logistics have highlighted how seemingly minor failures can have cascading effects on the broader immunization program (Sterman, 2000; Chukwu et al., 2018).

The Health Systems Framework is used to identify and categorize the systemic barriers affecting vaccine distribution, while General Systems Theory helps to model and anticipate the consequences of these barriers. The study suggested that inadequate training (a health workforce issue) and poor cold chain maintenance (a medical product and technology issue) interact to reduce vaccine potency. Likewise, insufficient data visibility (a health information systems issue) may lead to poor inventory decisions, stockouts, and missed vaccination opportunities. These theoretical models allow the study to move beyond superficial analysis and dig into the root causes of vaccine logistics challenges.

In Nigeria, studies have confirmed that challenges in the cold chain system, such as limited cold storage capacity and irregular electricity supply, have negatively impacted the delivery of potent vaccines (Akanbi et al., 2021; Okonkwo et al., 2019). Research also shows that health workers in many states, including the Southeast, often lack adequate training in vaccine handling and temperature monitoring (Ojo et al., 2019a). Furthermore, poor integration of logistics data into decision-making processes has led to inefficiencies in vaccine distribution (NPHCDA, 2022).

Another major contribution is the GAVI Alliance's Cold Chain Equipment Optimization Platform (CCEOP), which theoretically supports data-informed investment in cold chain infrastructure. By integrating procurement planning with facility readiness, CCEOP has shifted the focus from short-term procurement to long-term sustainability of cold chain systems (GAVI, 2021). Similarly, UNICEF's Vaccine Supply Chain Maturity Model provides a stepwise theoretical framework for identifying supply chain maturity levels across five domains: strategy, planning, data visibility, cold chain equipment, and human resources. This model serves as both a benchmarking and an improvement tool (UNICEF, 2020). It emphasizes the need for a holistic, integrated approach to improving vaccine logistics, one that recognizes interdependencies among people, infrastructure, processes, and data.

In the realm of scholarly research, Sterman (2000) and others have extended these theoretical frameworks through System Dynamics modelling, enabling researchers to simulate vaccine distribution systems under different constraints. This approach has been particularly useful for identifying bottlenecks and assessing the long-term impacts of strategic decisions. Studies applying this model in countries like India, Kenya, and Ethiopia have shown how stock-outs, transportation delays, and equipment failures have affected cold chain supply logistics. In Sub-Saharan Africa, theoretical studies have increasingly focused on adapting global models to the unique challenges of the region. For example, a review by Adetokunbo et al. (2022) emphasized that in Africa, successful immunization logistics requires combining global best practices with local knowledge. Their proposed framework incorporates community engagement, public-private partnerships, and political accountability elements often neglected in traditional WHO-centric models.

In Nigeria, the theoretical literature emphasizes decentralization and federal-state alignment in vaccine distribution. Chukwu et al. (2018) proposed a contextualized logistics framework that considers power asymmetries between federal and state actors, delays in fund disbursement, and regional insecurity. Their work underscores the importance of adaptive systems that can respond to local political, infrastructural, and epidemiological realities. Empirical studies often build on these theoretical propositions. For instance, Okonkwo et al. (2019) argued that no theoretical model can be effective unless logistics policies are backed by sustained investments and governance reforms. They proposed integrating supply chain theory with governance models to improve accountability and system resilience. This reinforces the argument that a hybrid approach combining technical frameworks with socio-political analysis is essential in Nigeria's complex challenges affecting cold chain logistics.

These theoretical studies collectively emphasized the need for a comprehensive approach to vaccine logistics. The WHO's building blocks and **Effective Vaccine Management (EVM)** framework help to define the components to be assessed (e.g., cold chain, human resources, data). Systems Dynamics and General Systems Theory highlight how these components interact. Meanwhile, Nigerian scholars remind us that success requires not only functional infrastructure but also political commitment, tailored strategies, and communications. By synthesizing these theoretical contributions, this study suggested a protocol suitable for assessing vaccine storage, transportation, and distribution challenges in southeast Nigeria to ensure that the study does not merely report operational issues but addresses the root systemic factors that underlie them.

Current issues and challenges of vaccine management services in Nigeria: the broader perspective

Human resource and training challenges

The role of skilled personnel in maintaining the vaccine cold chain cannot be overstated. However, several studies consistently show that health workers in many parts of Nigeria lack the necessary training and knowledge to manage vaccines effectively. In a nationwide assessment, Ojo et al. (2019a) reported that nearly 42% of vaccinators were unable to identify the correct temperature range for vaccine storage. Similar findings by Adeyemi et al. (2020a), in Kwara State, revealed that over half of the vaccinators had never attended any structured training sessions and often relied on information passed on informally by more experienced colleagues. This practice creates room for misinformation and poor handling procedures.

In some cases, vaccines were found stored alongside non-vaccine items such as soft drinks and laboratory reagents, suggesting a lack of understanding of cold chain standards. Akande et al. (2020) further documented that some health workers in their study could not correctly interpret Vaccine Vial Monitors (VVMs), a crucial tool in assessing vaccine deuteriation. These findings are troubling, as they suggest that even if the physical infrastructure exists, human error due to inadequate training can still lead to vaccine spoilage. Moreover, supervision and continuous professional development are often lacking. Regular refresher courses and on-the-job mentoring are not systematically embedded in the health system, leading to stagnation in knowledge and skills. This deficiency poses a significant threat to vaccine quality, efficacy and outcomes.

Cold chain infrastructure and equipment availability

A fundamental requirement for immunization services is the availability of functional cold chain equipment. Yet across Nigeria, there is a glaring mismatch between equipment needs and actual availability. A nationwide audit by the National Primary Health Care Development Agency (NPHCDA, 2022) revealed that more than 30% of primary health care (PHC) facilities lacked any form of functional refrigerator. In some facilities, cold boxes were used as the sole method of storage, even for extended periods, which goes against best practices. In a focused study conducted in Enugu and Ebonyi States, Okonkwo et al. (2019) found that about 40% of cold chain equipment had not been serviced in over 24 months. The authors also noted that most of these facilities experienced frequent power outages, rendering even functional refrigerators unreliable. The situation was slightly better in facilities equipped with solar-powered refrigeration units, which maintained a more consistent temperature range and reduced vaccine wastage. The lack of backup power sources was another recurring issue. Many facilities dependent on the national power grid and had no functional generators or fuel to keep vaccines at optimal temperatures during outages. Consequently, temperature excursions were frequent, especially during weekends and public holidays when monitoring was less rigorous. These findings point to the urgent need for investment not just in equipment procurement but also in infrastructure maintenance and energy sustainability.

Temperature control and monitoring

The monitoring of vaccine temperature is the backbone of an effective cold chain to ensure the maintenance of their potency and efficacy. A study suggested poor temperature control practices across many PHC facilities in Nigeria, and this is further complicated by the poor electricity supply system in the country (Okonkwo et al., 2019). A WHO-backed survey in 2020 focusing on the southeast region found that only 45% of health facilities maintained temperature logs consistently. The facilities lacked digital temperature monitoring system and still rely on manual documentation of temperatures. These manual records are prone to manipulation, loss, or inaccuracy. Akanbi et al. (2021) conducted an observational study in North Central Nigeria and found that 29% of surveyed facilities had experienced at least one refrigerator failure in the preceding month. In most of these cases, no backup system was in place, and vaccines were either relocated (often improperly) or discarded. The study concluded that a lack of maintenance culture and reactive rather than preventive repair systems were the main contributors to equipment breakdowns.

Transportation barriers

Transport logistics are another major pain point in vaccine distribution. While cold chain equipment at storage points is vital, the system also depends on the safe and timely movement of vaccines from national to regional, local, and facility levels. Chukwu et al. (2018) assessed vaccine transport mechanisms across five Nigerian states and found irregular delivery schedules and severe vehicle shortages. Many LGAs lacked dedicated vehicles for vaccine transportation, relying instead on general-purpose or borrowed vehicles, often without cold boxes or ice packs. Most of the LGAs exceeded the WHO-recommended maximum 30-day interval between deliveries. Road conditions further complicate the situation. Many rural areas are inaccessible especially during rainy seasons. Ng'oda (2026) and Wanjohi et al. (2020) highlighted similar problems in rural Kenya, noting that vaccines often arrived late or damaged due to long, unregulated journeys.

UNICEF's (2021) logistics review showed that only 12% of LGAs in Nigeria had a dedicated, functional vaccine transport system. In most cases, ad hoc arrangements are made, and vaccine safety is left to chance. Without proper transport insulation or trained handlers, the cold chain is frequently broken during transit.

Distribution challenges and insecurity

Even when vaccines are available and transport is arranged, distribution can be severely affected by insecurity and bureaucratic delays. In conflict-prone areas of the South-East, such as parts of Anambra and Imo States, security threats have caused frequent disruptions to routine vaccination activities. Eze et al. (2021) documented that during periods of civil unrest, health workers suspended rallies and campaigns on vaccine use due to insecurity and lack of guarantee for their safety. Nwokolo and Ibeh (2020), in a study in Ebonyi State, suggested that distribution was delayed due to lack of disbursement of funds and administrative bottlenecks. Healthcare facilities often lack the autonomy or resources to respond promptly to emerging needs. As a result, last-mile delivery to PHCs can be delayed for days or weeks.

Logistics data utilization and decision-making

Effective decision-making in vaccine logistics hinges on the timely, and accurate use of data. Yet, in many parts of Nigeria, logistics data is either poorly collected or not used at all. Olatunji et al. (2022), in their study of 100 PHC facilities, found that only 36% had staff trained in data management. Worse still, fewer than 20% regularly use logistics data to plan vaccine orders or manage stock levels. Although the adoption of digital tools such as the District Health

Information Software 2 (DHIS2) has shown some promise, coverage remains patchy. The NPHCDA (2022) reported that facilities using DHIS2 had fewer stock-outs. However, in many rural LGAs, staff are unfamiliar with the platform or lack access to internet services and functional devices.

Additionally, data collected is often not analyzed locally but sent up the chain for central processing, causing delays in local decision-making. This limits the responsiveness of the system to real-time needs and erodes confidence in the utility of data tools. Vaccination logistics do not operate in isolation but rather form part of a complex web of infrastructure, policy, personnel, and data systems. Together, these components determine the reliability and effectiveness of vaccine delivery, especially in resource-constrained settings such as southeast Nigeria.

From a theoretical standpoint, two dominant models, the WHO Health Systems Framework and the General Systems Theory, help explain how various logistics components interact. The WHO framework, with its six building blocks, provides a structured lens to examine how deficits in the health workforce, medical products, impact the program. On the other hand, General Systems Theory emphasizes feedback loops and systemic delays, illustrating how inefficiencies in one part of the supply chain (such as stock reporting) can lead to broader disruptions, like vaccine stockouts or delays in immunization operations and campaigns. These theoretical lenses are particularly useful for understanding the fragility of vaccine logistics in volatile environments.

There was increasing emphasis on structured tools. Each of these models offers a roadmap for identifying weaknesses and building resilience and sustainability into the system. The EVM tool provides benchmarks for monitoring the capacity of vaccines storage, maintenance, and distribution efficiency, while GAVI's CCEOP prioritizes sustainable investment in cold chain technologies based on real-time data and infrastructure needs. However, scholars argue that global models cannot simply be imported wholesale into African contexts without adaptation. Nigerian researchers, such as Chukwu et al. (2018) and Adetokunbo et al. (2022), indicated that contextualizing these models is essential for understanding the dynamics. They suggest that successful logistics systems must consider Nigeria's federal structure, regional disparities, political bottlenecks, and infrastructural limitations.

In addition, factors such as insecurity and local governance practices significantly influence how vaccine logistics operate at the grassroots level. Empirical studies provide grounded evidence to support these theoretical claims. For example, data from primary health care (PHC) centers across Nigeria show that over 30% of facilities lack functional refrigerators, and many rely on obsolete equipment with poor temperature regulation (NPHCDA, 2022). Such deficiencies are compounded by inconsistent electricity supply, especially in rural areas. Even where solar-powered fridges are available, maintenance is often lacking, leading to equipment breakdowns and loss of vaccine potency.

Another persistent challenge lies in human resources and training. Studies show that a significant proportion of vaccinators have never received formal training in cold chain management. In some instances, health workers rely on outdated practices or peer-passed knowledge, increasing the risk of errors in vaccine handling and storage (Adeyemi et al., 2019; Akande et al., 2020). Moreover, staffing shortages mean that available personnel are often overburdened, with limited supervision or opportunities for refresher courses. These human capital constraints are often overlooked but are critical to ensuring the last-mile effectiveness of any vaccine program.

The issue of data visibility and logistics information systems also looms large. Although platforms like DHIS2 have been introduced to digitize vaccine logistics, uptake and utilization remain low in many areas, particularly in hard-to-reach local government areas (LGAs). Research shows that only a minority of health facilities use real-time data for planning stock levels, and very few have dedicated staff trained in logistics data management (Olatunji et al., 2022). This lack of data use means that facilities are often reactive rather than proactive, leading to frequent stockouts and inefficient distribution.

Transportation barriers further exacerbate these issues. Vaccine delivery vehicles are scarce, and in many cases, health workers rely on motorcycles or even public transport to carry sensitive biological materials. Studies have documented that those vaccines often travel long distances on bad roads, without temperature monitoring or insulation, increasing the risk of thermal damage (Chukwu et al., 2018; UNICEF, 2021). In some LGAs, delivery intervals stretch far beyond the recommended 30-day cycle, undermining routine immunization schedules.

Another under-discussed but significant issue is security. In states like Anambra and Imo, growing insecurity has led to sporadic vaccine distribution, missed immunization days, and loss of public trust. Health workers in affected areas often face threats to their safety, which discourages them from participating in outreach or distribution activities. In such settings, even the best logistical planning can be derailed by unpredictable security challenges (Eze et al., 2021). Despite these challenges, the literature offers glimmers of hope. Some studies highlight successful interventions, such as the deployment of solar fridges, training programs for health workers, and improved integration of logistics data into national systems. Facilities that have adopted these innovations tend to report fewer stockouts, higher equipment uptime, and better vaccination coverage. These findings suggest that targeted investments in infrastructure, training, and governance can yield tangible improvements in vaccine logistics.

Several gaps still abound in published studies. First, few studies focus specifically on the southeast region of Nigeria, despite its unique topography, sociodemographic inclinations, and infrastructural challenges. Most national studies aggregate data, which can obscure regional disparities. Second, while quantitative assessments of cold chain equipment and training levels are common, fewer studies incorporate qualitative insights from frontline health workers. Their lived experiences could provide valuable information about practical bottlenecks and potential solutions. Third, while digital tools like DHIS2 have been celebrated, there is limited empirical evaluation of their real-world effectiveness at the LGA and facility levels.

Limitations

This study is a narrative review and did not explore the protocols of a systematic review in search, scope, and the evaluation of evidence and studies. The study may have been associated with selection, and publication bias. The article search, selection process for studies and methods, did not incorporate quality assessment and protocol and may not be reproducible. Some critical data may have been omitted in the search process.

Conclusion

The study suggested a lack of skilled personnel in maintaining the vaccine cold chain and structured training for people who handle vaccine services. There was a mismatch between equipment needs for vaccine services and actual availability. Temperature monitoring and control were poorly practiced across many PHC facilities. Most of the facilities lacked dedicated vehicles for vaccine transportation and relied instead on general-purpose or hired vehicles, often without cold boxes or ice packs. The logistics data were either poorly collected or underutilized in decision-making. The collected data is often not analyzed locally but sent up the chain for central processing, causing delays in local decision-making. There was an increasing emphasis on structured tools that offer a roadmap for identifying weaknesses and building resilience in supply chains. However, scholars argued that global models need contextualization and cannot simply be imported wholly into the African context without adaptation. There is limited empirical evaluation of the real-world effectiveness of digital tools in the facilities. Lack of maintenance culture and reactive rather than preventive repair systems contributed greatly to equipment breakdown and the ultimate loss of some vital infrastructure.

Conflict of Interest: The authors have none to declare.

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