Transportation and Distribution Challenges of Fresh Vegetables in Urban Nigeria: A Systematic Review

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Abstract

Nigeria's rapid urbanisation has intensified demand for fresh vegetables, yet inefficient transportation and distribution systems critically undermine three dimensions of urban food security: availability, as post-harvest losses reduce effective supply; affordability, as transport costs inflate retail prices; and access, as infrastructure gaps restrict market reach for both farmers and consumers. Post-harvest losses ranging from 30–60% occur during transit from rural production zones to urban markets, driven by poor road infrastructure, inadequate cold chain facilities, and suboptimal handling practices. This loss range is crop-specific and regionally variable: tomatoes record the highest losses (45–60%), followed by leafy vegetables (40–50%), peppers (30–40%), and onions (20–30%), with losses intensifying during the rainy season when road conditions deteriorate. This review systematically examines vegetable transportation and distribution systems in Nigerian urban centres, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. A structured search across Google Scholar, Web of Science, African Journals Online (AJOL), and Scopus, combined with grey literature screening, yielded 47 relevant sources from an initial pool of 284 after title/abstract and full-text screening. Key findings reveal that vegetables travel an average of 200–800 kilometres along major northern-to-southern corridors (e.g., Kano–Lagos; Jos–Abuja), with trucking costs accounting for 40–60% of final retail prices depending on distance, route conditions, and commodity type. Distribution remains predominantly informal, characterised by multi-layered intermediation and weak market information systems. Emerging interventions including mobile cold-storage units (demonstrating 40–60% spoilage reduction in pilot deployments), digital marketplaces, and cooperative aggregation models show promise, though scaling is constrained by financing gaps, electricity unreliability, and weak policy coordination. Infrastructure development, phased cold chain investment targeting major transit nodes and wholesale markets, and coordinated stakeholder engagement are essential for reducing losses and enhancing urban food security in Nigeria.

Keywords: vegetable distribution, transportation, urban centres, post-harvest losses, supply chain, food security, PRISMA, Nigeria.

1.0 Introduction

Vegetables constitute critical components of dietary diversity, providing essential micronutrients that address malnutrition challenges in developing countries (Weinberger & Lumpkin, 2007). Nigeria's urban population, projected to reach 187 million by 2050, faces growing vegetable demand, yet per capita consumption remains below WHO

recommendations of 400 grams daily (Ruel *et al*., 2005). Urban centres depend heavily on rural production zones, necessitating efficient transportation and distribution systems. Failures in these systems directly compromise food security across three dimensions: availability, through physical losses that reduce effective supply; affordability, through transport cost mark-ups that inflate retail prices by 40–60%; and access, through infrastructure gaps that restrict consumer and farmer market reach.

Nigerian vegetable supply chains experience substantial inefficiencies manifested through post-harvest losses estimated between 30–60% across vegetable types and seasons (Kitinoja & AlHassan, 2012; Abass *et al*., 2014). Tomatoes are most vulnerable (45–60% losses), followed by leafy vegetables (40–50%), peppers (30–40%), and onions (20–30%), reflecting differences in moisture content, respiration rate, and mechanical fragility. Inadequate transportation infrastructure, absence of cold chain facilities, and poor handling practices during transit contribute to physical damage, quality deterioration, and complete spoilage (Idah *et al*., 2007). These losses translate to annual economic losses exceeding ₦500 billion, affecting smallholder farmers' incomes and elevating urban food prices (Adeoye *et al.,* 2009). Perishable vegetables including tomatoes, peppers, and leafy greens suffer disproportionately, with losses intensifying during rainy seasons when road conditions deteriorate severely.

This review synthesises available evidence on vegetable transportation and distribution systems in Nigerian urban centres, examining infrastructure constraints, loss mechanisms, market structures, and emerging innovations to inform evidence-based interventions. The review objectives are to: (1) characterise vegetable transportation systems linking rural production zones to urban markets; (2) analyse distribution channels and market structures in Nigerian urban centres; (3) assess post-harvest losses during transportation and distribution; and (4) identify innovations and interventions improving supply chain efficiency.

2.0 Theoretical Framework

Understanding vegetable transportation and distribution in Nigerian urban centres requires an integrated analytical lens drawing on five complementary theoretical perspectives: agricultural supply chain management, perishable product logistics, market structure theory, post-harvest loss frameworks, and the infrastructure-development nexus. Rather than treating these as independent constructs, this review deploys them as an interconnected framework in which each dimension shapes the others.

Agricultural supply chain management frames the movement of vegetables from farm to consumer as a coordinated system of actors, farmers, transporters, wholesalers, and retailers, whose collective efficiency determines product availability, cost, and quality (Van der Vorst *et al*., 2007; Siddh *et al*., 2018). For perishable produce, this framework intersects directly with perishable product logistics: vegetables degrade continuously after harvest due to respiration, transpiration, enzymatic reactions, and microbial activity, all temperature-dependent processes (Kader, 2013). The 'time-temperature tolerance' concept establishes that shelf life is a function of cumulative heat and time exposure, making rapid transit and cold chain infrastructure essential rather than optional (Jedermann et al., 2014; Mercier *et al.*, 2017).

Market structure theory explains how informal, multi-tier distribution channels generate information asymmetries and power imbalances that disadvantage smallholder farmers (Barrett, 2010; Reardon *et al*., 2009). In Nigerian vegetable markets, power concentration among urban wholesalers and transporters, who control logistics and price discovery, compresses farmer margins while sustaining consumer price inflation (Mgbenka & Mbah, 2016). These dynamics are reinforced by the post-harvest loss framework (FAO, 2019), which categorises losses as physical (damage or spoilage), quality (deterioration), and nutritional

(vitamin loss), each linked to biological, physical, chemical, and environmental causes that are amenable to targeted technical and institutional interventions (Affognon *et al*., 2015).

Underpinning all of these dimensions is the infrastructure-development nexus: road quality directly determines transportation costs, transit times, vehicle operating costs, and produce exposure to mechanical damage (Dorosh et al., 2012). Market infrastructure, including storage, utilities, and sanitation which further shapes price levels, food safety, and trader costs (Cadilhon et al., 2003). Infrastructure investment creates multiplier effects by lowering transaction costs, expanding market reach, and strengthening farmer-market integration (Jacoby & Minten, 2009). Collectively, these five frameworks provide this review's analytical scaffolding: inefficiencies at any node, infrastructure, logistics, market structure, or institutional, cascade through the system, generating losses, raising costs, and undermining food security.

2.1 Vegetable Production and Urban Demand in Nigeria

Nigeria's vegetable production concentrates in northern states Kaduna, Kano, Plateau, and Bauchi, accounting for an estimated 65% of national output, while major consumption centres are located in southern urban areas including Lagos, Port Harcourt, and Ibadan (Oseni & Masarirambi, 2011).

This geographic separation between production and consumption is the primary structural driver of transportation pressure in Nigeria's vegetable supply chain. Principal vegetables traded include tomatoes (annual production approximately 2.3 million tonnes), peppers (1.8 million tonnes), onions (1.5 million tonnes), and leafy vegetables including amaranth, spinach, and lettuce (FAOSTAT, 2023). Lagos alone consumes approximately 150,000 tonnes of vegetables monthly, with an estimated 70% sourced from northern states (Adeoye *et al.*, 2009) figures that underscore the logistical scale and corridor-specific nature of Nigeria's vegetable distribution challenge.

The resulting supply chains span estimated distances of 200–800 kilometres along major corridors (e.g., Kano–Lagos: ~1,030 km; Jos–Abuja: ~280 km; Kaduna–Port Harcourt: ~950 km), with corridor-specific transit times ranging from 6–24 hours depending on road conditions, vehicle type, and checkpoint frequency (Babalola *et al*., 2010). These distances and durations are not static: rainy season road degradation extends transit times by an estimated 40–80% on vulnerable routes, creating seasonal spikes in both losses and logistics costs.

Urban centres exhibit per capita vegetable consumption rates approximately 40% higher than rural areas, driven by income levels and dietary diversification (Ruel et al., 2005). Seasonal production peaks during the dry season (November–March) create glut-scarcity cycles that introduce additional logistics strain, compressing distribution windows during glut periods and intensifying competition for scarce transport during scarcity periods. Nigeria's vegetable trade generates estimated annual revenues of ₦400 billion, supporting livelihoods across approximately 15 million actors in production, transportation, and distribution (FMARD, 2020). These estimates, while subject to data limitations, signal the sector's economic significance and its vulnerability to systemic distribution failures.

3.0 Methodology

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, which guided the search strategy, screening process, data extraction, and reporting. Adherence to PRISMA principles ensures methodological transparency and reproducibility. A systematic literature search was conducted across multiple databases including Google Scholar, Web of Science, African

Journals Online (AJOL), and Scopus during October-November 2024. To manage the limitations of Google Scholar, which can return non-curated results, all Google Scholar-sourced articles were cross-verified against peer-reviewed databases (Scopus, Web of Science, or AJOL) to confirm indexing status and eliminate duplicates. Duplicate records identified across databases were removed prior to screening.

Search terms combined Boolean operators: ("vegetable" OR "tomato" OR "pepper") AND ("transportation" OR "distribution" OR "supply chain" OR "logistics") AND ("Nigeria" OR "urban" OR "city") AND ("post-harvest loss" OR "food loss" OR "market"). Grey literature from Food and Agriculture Organization (FAO), International Food Policy Research Institute (IFPRI), and Federal Ministry of Agriculture and Rural Development (FMARD) supplemented academic sources. Searches covered publications from 2010-2024, with seminal earlier works included where foundational relevance existed.

Seven seminal works predating 2010 were retained in the final synthesis. These were included only where they constituted foundational theoretical contributions with no adequate contemporary substitute, and where their core empirical claims were corroborated by at least one post-2010 study in the review corpus

Inclusion criteria encompassed: peer-reviewed journal articles and authoritative institutional reports; studies addressing Nigerian vegetable transportation, distribution, or supply chains; empirical research employing quantitative or qualitative methodologies; and systematic reviews with Nigerian applicability.

Exclusion criteria eliminated: non-Nigerian studies lacking documented contextual similarity to Nigeria's infrastructural, institutional, or climatic conditions (i.e., studies without transferable applicability to Nigeria's supply chain context); production-focused research excluding distribution aspects; studies exclusively examining non-perishable crops; conference abstracts without full-text availability; and publications from predatory journals.

Predatory journal identification employed a multi-pronged verification approach: Beall's List (as a historical reference baseline), the Directory of Open Access Journals (DOAJ) indexing status, and direct confirmation of peer-review processes via publisher websites. This multi-source approach compensates for Beall's List no longer being officially updated.

Initial database searches identified 284 potentially relevant publications. Title and abstract screening reduced this to 96 articles for full-text review. After detailed assessment against the inclusion criteria, 47 sources were retained for final synthesis. A PRISMA-compliant flow diagram detailing these screening stages is presented in Figure 1. These 47 sources comprised 31 peer-reviewed journal articles, 12 institutional reports, and 4 government publications.

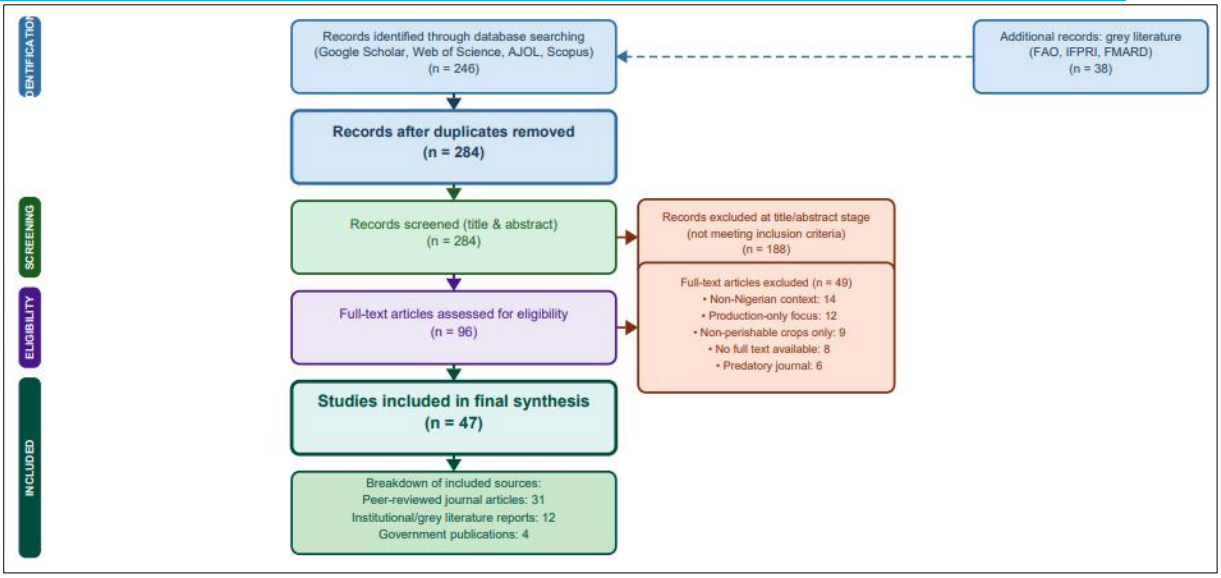

Figure 1: PRISMA Flow Diagram – Systematic Review of Vegetable Transportation & Distribution in Urban Nigeria

Thematic content analysis was conducted deductively, guided by the five theoretical frameworks outlined in Section 1.1. Coding was performed manually by the lead author, with cross-verification by a co-author on a 20% random sample of sources to ensure consistency. Themes were derived a priori from the conceptual framework and refined iteratively through the review process. No software-assisted coding tools were used. Quality assessment of included studies was conducted using an adapted CASP (Critical Appraisal Skills Programme) checklist for systematic reviews, evaluating: (1) methodological rigour and study design appropriateness; (2) sampling adequacy and representativeness; and (3) contextual relevance to Nigerian urban vegetable distribution. Studies rated as low quality on all three dimensions were excluded from the final synthesis. Thematic content analysis organised findings into five major themes: transportation systems, distribution channels, post-harvest losses, challenges and constraints, and innovations and interventions.

4.0 Thematic Findings

4.1 Transportation Systems and Infrastructure

Vegetables move from rural production areas to urban markets predominantly via road transportation. This is done through the use of medium-capacity trucks (5-10 tonnes), pickup vans, and motorcycles for final distribution (Balogun *et al.*, 2014). Long-haul transportation from northern states employs refrigerated trucks, constituting less than 5% of the total vegetable transport fleet, with ambient-temperature vehicles dominating despite perishability concerns (Kitinoja & AlHassan, 2012). Transportation costs represent 40-60% of final retail prices in urban markets, varying by distance, road conditions, and fuel prices (Adeoye *et al.*, 2009).

Nigeria's road network exhibits severe deterioration, with approximately 60% of federal roads rated in poor or very poor condition (Ajiboye & Afolayan, 2009). This figure is consistent with more recent infrastructure assessments, which indicate limited rehabilitation progress on key agricultural corridors (Federal Ministry of Works, 2021). Key vegetable transportation routes, including Kano–Lagos (1,030 km), Jos–Abuja (280 km), and Kaduna–Port Harcourt (950 km), experience frequent delays from checkpoints, road damage, and congestion (Babalola *et al.*, 2010). These corridor-specific conditions translate directly into loss gradients: produce on

longer, more degraded routes accumulate higher losses than shorter, better-maintained corridors.

Rural feeder roads connecting farms to primary markets remain predominantly unpaved, complicating aggregation and increasing handling frequency that damages produce. Transit duration critically affects vegetable quality, with tomatoes transported over 12 hours showing 25-40% higher spoilage rates compared to those reaching markets within 6 hours (Idah *et al*., 2007).

Recent studies confirm that these quality-transit time relationships hold across commodity types, with Umar et al. (2018) finding comparable spoilage gradients for tomatoes in Kaduna State, and Chijioke et al. (2020) documenting similar patterns for leafy vegetables in Abuja wholesale markets. Vehicle types utilized often lack proper ventilation, cushioning, or temperature control, subjecting vegetables to mechanical damage and heat stress during transit. Seasonal variations intensify transportation challenges, as rainy season road degradation extends transit times by 40-80% on certain routes (Babalola *et al*., 2010).

Taken together, the evidence on transportation infrastructure reveals a mutually reinforcing cycle: poor road quality increases transit time, which elevates spoilage rates and fuel costs, which in turn inflate retail prices and reduce farmer returns, generating little incentive for supply chain investment. Breaking this cycle requires targeted infrastructure investment on high-volume vegetable corridors, rather than generalised road rehabilitation programmes.

4.2 Distribution Channels and Market Structures

Vegetable distribution networks in Nigerian urban centres operate predominantly through informal channels involving multiple intermediaries between farmers and consumers (Tobin et al., 2016). Typical supply chains comprise farmers, village aggregators, long-distance transporters, urban wholesalers, retailers, and consumers, with each node adding 10-25% markup (Adeoye *et al.*, 2009). Market women dominate retail distribution, controlling approximately 80% of urban vegetable trade through established market stall networks (Babalola & Isitor, 2014).

Urban wholesale markets including Mile 12 (Lagos), Wuse Market (Abuja), and Sabon Gari (Kano) serve as primary distribution hubs receiving bulk consignments from production zones (Umar *et al*., 2018). These markets operate with minimal regulation, limited storage infrastructure, and no quality grading systems, resulting in price volatility and information asymmetries (Mafimisebi, 2012). Power dynamics within supply chains favour urban wholesalers and transporters who control access to markets and price determination, often squeezing farmers' profit margins to 15-25% of final consumer prices (Aworh, 2015).

The governance deficit underlying these market structures is substantial. Regulatory frameworks for vegetable quality standards, market operations, and food safety remain fragmented across multiple agencies, including the National Agency for Food and Drug Administration and Control (NAFDAC), State Ministries of Agriculture, and local market authorities, with overlapping mandates and weak enforcement capacity (Ogunkan, 2026). This institutional fragmentation enables informal actors to operate outside quality and hygiene standards, perpetuating the absence of grading systems and the price opacity that disadvantages farmers. Strengthening market governance requires not merely additional regulation, but clearer institutional mandates, inter-agency coordination, and incentive-compatible compliance mechanisms.

Supermarket chains constitute emerging formal distribution channels, accounting for approximately 3% of urban vegetable retail but growing at 15-20% annually in major cities (Reardon *et al*., 2003). These formal channels demand higher quality standards and consistent supply, challenging traditional distribution networks but potentially reducing loss rates through improved handling and storage. Market information systems remain underdeveloped, with price dissemination occurring through informal networks and mobile phone contacts rather than organized platforms (Aker & Mbiti, 2010).

It is important to note that informal distribution channels, while characterised by inefficiencies, also demonstrate adaptive resilience. Their flexibility in absorbing seasonal supply shocks, low barriers to entry for smallholder participation, and social capital-based credit systems provide functions that formal alternatives have yet to replicate at scale in the Nigerian context. Policy interventions should therefore seek to formalise and upgrade informal systems rather than displace them. The distribution system, as a whole, reflects a governance-and-market-structure problem as much as a technical one. Addressing it requires simultaneous attention to information asymmetries, institutional coordination, gender-equitable access to credit and infrastructure, and regulatory clarity not simply physical infrastructure upgrades

4.3 Post-Harvest Losses and Quality Deterioration

Post-harvest losses during transportation and distribution of vegetables in Nigeria range from 30–60%, varying by vegetable type, season, and handling practice (Kitinoja & AlHassan, 2012). As noted in Section 4.1, tomatoes experience the highest loss rates (45–60%), followed by leafy vegetables (40–50%), peppers (30–40%), and onions (20–30%). These variations reflect differences in moisture content, cell structure fragility, and sensitivity to mechanical bruising, not simply handling carelessness. Physical damage from poor packaging and rough handling during loading, transit, and unloading accounts for 40–50% of total losses (Adeoye et al., 2009).

Inappropriate packaging using jute sacks, woven baskets, and wooden crates without cushioning materials causes bruising, crushing, and mechanical injury to vegetables (Arah et al., 2015). Temperature-induced deterioration from ambient transportation in tropical heat accelerates respiration rates, moisture loss, and microbial spoilage, particularly affecting highly perishable leafy vegetables (Aworh, 2008). Extended transit times exceeding optimal thresholds compound these factors, with each additional 6 hours in transit increasing tomato losses by approximately 8–12% (Babalola *et al.*, 2010).

The economic implications are substantial, though estimates vary by source and scope. Annual losses are estimated at ₦500–800 billion nationally (FMARD, 2020), though these figures should be interpreted as planning-scale estimates rather than precise economic measurements given data limitations in the sector. Quality deterioration, manifested through wilting, discolouration, weight loss, and reduced nutritional content, diminishes market value even when vegetables remain technically saleable, creating welfare losses for consumers who receive nutritionally depleted produce at elevated prices. Seasonal patterns show intensified losses during the rainy season (June–September) when road conditions deteriorate and humidity accelerates spoilage processes (Babalola *et al*., 2010).

4.4 Challenges and Constraints

Infrastructure deficits constitute primary constraints affecting vegetable distribution efficiency in Nigerian urban centres, as detailed in Section 4.1. Cold chain infrastructure remains virtually absent, with Nigeria possessing less than 10% of the required refrigerated storage capacity relative to vegetable production volumes, a national-level estimate based on FAO benchmarks

applied to FMARD production data (Aworh, 2015). Urban wholesale markets lack basic storage facilities, forcing traders to sell quickly regardless of prevailing prices to minimise spoilage losses.

Financial constraints limit smallholder farmers' and small-scale traders' capacity to invest in improved packaging materials, refrigerated transportation, or quality-enhancing technologies (Tobin et al., 2016). Access to credit for supply chain investments remains restricted, with commercial banks perceiving agricultural trade as high-risk (Mafimisebi, 2012). Women traders, who dominate retail distribution, face compounded financial exclusion, as they are less likely than male counterparts to hold formal collateral, access institutional credit, or participate in male-dominated trader associations that facilitate informal credit networks (Babalola & Isitor, 2014; Kehinde et al., 2018). Gender-sensitive credit and capacity-building programmes are therefore essential components of any supply chain improvement strategy. Market information asymmetries disadvantage farmers who lack real-time price data from urban markets, reducing bargaining power and income capture (Aker & Mbiti, 2010).

Security challenges on certain transportation routes increase transit costs and risks, with extortion at checkpoints adding ₦50–150 per checkpoint to transportation expenses (Babalola & Isitor, 2014). Regulatory frameworks governing vegetable quality standards, market operations, and transportation remain weak or poorly enforced across most urban centres. Climate variability affects production timing and road accessibility, introducing supply unpredictability that complicates logistics planning (Umar *et al*., 2018).

Recent evidence indicates that climate variability is an escalating rather than static constraint: increasing rainfall intensity events in Nigeria's Middle Belt and the South-South are causing more severe and more frequent road washouts on key agricultural corridors, with projected intensification under medium-emission climate scenarios (Nwosu et al., 2023). Supply chain actors have developed limited adaptive capacity, primarily through route diversification and price speculation, but systemic climate resilience planning for vegetable distribution infrastructure is largely absent.

4.5 Innovations and Interventions

Mobile cold storage units deployed in selected urban markets provide short-term refrigeration, reducing spoilage rates by 40–60% compared to ambient storage in pilot settings (Kitinoja et al., 2011). Private sector initiatives, most notably ColdHubs, which has established solar-powered walk-in cold rooms at strategic markets, have demonstrated tangible impact, serving over 5,000 smallholder farmers and traders across Nigerian states (ColdHubs, 2022). However, scaling this model faces significant barriers: ColdHub units depend on reliable solar irradiation and functioning solar panels, making them vulnerable in consistently overcast regions or where maintenance capacity is limited. User adoption has also been constrained by affordability, as daily rental fees represent a significant share of small traders' margins, and by unfamiliarity with cold chain handling requirements. Sustained scale-up will require concessional financing, last-mile technical support, and integration into existing trader networks.

Improved packaging technologies, such as ventilated plastic crates, reduce physical damage by 35–50% compared to traditional jute sacks (Arah et al., 2015). Despite this demonstrated effectiveness, adoption rates remain low, primarily due to high upfront capital costs relative to traders' incomes, limited awareness of the link between quality and price premiums, and the absence of institutional procurement standards that would reward improved packaging through price differentiation.

Digital platforms connecting farmers directly to urban retailers and consumers reduce intermediation layers, improving price transmission and reducing transaction costs by an estimated 15–25% in documented pilot programmes (Wan and Li, 2022). However, digital platform adoption is conditioned on smartphone access, digital literacy, reliable mobile data connectivity, and trust in digital payment systems all of which remain unevenly distributed across Nigerian smallholder populations. Evidence of sustained impact beyond pilot phases is limited, and platform governance models (fee structures, dispute resolution) remain underdeveloped.

Cooperative aggregation models pool smallholder production to achieve economies of scale in transportation and market access, enhancing bargaining power and reducing per-unit logistics costs (Adeoye et al., 2009). Public-private partnerships have rehabilitated market infrastructure in cities including Ibadan and Kano, providing covered stalls, improved drainage, and organised storage areas (FMARD, 2020).

Policy interventions including the Federal Government's Agricultural Transformation Agenda (ATA) and the more recent National Agricultural Technology and Innovation Policy (NATIP 2020–2030) have supported cold chain infrastructure development and rural road rehabilitation (FMARD, 2020). However, implementation has remained geographically concentrated in accessible urban-peri-urban zones, with limited reach to the rural feeder roads and primary assembly markets where losses are most acute. Impact evaluation evidence for these programmes, particularly cost-effectiveness analysis under Nigerian operational conditions, is largely absent from the published literature, limiting the basis for replication and scaling decisions.

Processing enterprises converting fresh vegetables into dried, canned, or frozen products provide alternative outlets that reduce fresh market distribution pressure, though current penetration remains below 10% of total vegetable output (Aworh, 2015). Expanding this sub-sector requires investment in processing infrastructure, cold storage for processed goods, and market development to shift consumer preferences in a culture where fresh vegetables are strongly preferred.

5.0 Discussion

The findings of this review reveal that vegetable transportation and distribution in Nigerian urban centres constitutes a complex socio-technical system in which infrastructure constraints, market governance failures, institutional weaknesses, and technological gaps interact to generate compounding inefficiencies. Viewed through the integrated theoretical framework advanced in Section 1.1, these failures are not isolated but mutually reinforcing: poor road infrastructure extends transit times (infrastructure-development nexus), accelerating spoilage through heat and mechanical damage (perishable logistics); shortened shelf life forces distress sales by farmers (market structure theory), which depress farm-gate prices and reduce investment incentives; and weak institutions fail to enforce standards or coordinate cold chain development (supply chain management), sustaining the cycle.

Infrastructure emerges as the fundamental bottleneck. Nigeria's infrastructure deficit requires estimated investments of ₦3 trillion for road rehabilitation and ₦500 billion for cold chain development to achieve adequate vegetable distribution efficiency (FMARD, 2020). While these are government planning-scale projections rather than independently audited figures, they signal the magnitude of the investment required and the limits of private-sector action alone.

Post-harvest losses represent both technical challenges, addressable through improved handling, packaging, and cold storage, and systemic issues rooted in market power imbalances. The post-harvest loss framework (FAO, 2019) highlights the full causal chain: biological, physical, chemical, and environmental drivers of deterioration are each implicated in the Nigerian context, and each requires different intervention types. Technical solutions (cold chain, ventilated crates) address biological and environmental drivers; institutional solutions (grading standards, cooperative structures) address failures in physical handling and market information.

A critical nuance in interpreting informal distribution systems is required. While this review has documented their role in perpetuating inefficiencies through excessive intermediation, price opacity, and resistance to quality standards, informal channels simultaneously demonstrate adaptive strengths that formal alternatives cannot yet replicate at scale: flexibility to absorb seasonal supply shocks, low transaction costs relative to formal retail, and social capital-based credit mechanisms that sustain smallholder participation. Policy approaches that seek to displace informal systems risk eliminating these adaptive functions while failing to deliver formal alternatives at the required scale and cost. Upgrading and formalising informal systems through market infrastructure investment, information system development, and cooperative formation is a more promising and equitable pathway.

The gender dimension of vegetable distribution warrants more sustained analytical attention than it has historically received. Market women dominate retail distribution yet face compounded constraints: limited access to formal credit, exclusion from male-dominated trader networks, and disproportionate exposure to deficiencies in market infrastructure (Babalola & Isitor, 2014; Kehinde *et al.*, 2018). From a supply chain management perspective, these constraints represent a system-level inefficiency; the largest segment of the distribution workforce is systematically under-resourced. Gender-responsive interventions, including women-targeted credit facilities, cooperative structures designed for female participation, and child-care provisions at market sites, should be integrated as standard components of supply chain development programmes, not treated as peripheral social policy.

Climate change presents an emerging systemic risk that is under-acknowledged in the existing literature. Increasing rainfall intensity, prolonged flooding events, and temperature extremes are already extending transit times, damaging feeder road surfaces, and disrupting seasonal production calendars, thereby compounding existing logistics fragility (Nwosu *et al.*, 2023). Future supply chain planning must incorporate climate exposure assessments for key corridors and markets, and infrastructure investments should be designed to climate-resilient standards, particularly for road surfaces and market drainage systems.

Policy priorities, viewed through the integrated framework, require sequencing across three-time horizons. In the short term (0–2 years), interventions should focus on: farmer and trader capacity building in handling and packaging practices; mobile and digital market information systems to reduce price asymmetries; and regulatory harmonisation to clarify institutional mandates for market oversight. In the medium term (2–5 years), priority should shift to: cold chain node development at major wholesale markets and transit hubs; cooperative aggregation support to build smallholder logistics capacity; and rehabilitation of the highest-traffic vegetable corridors. In the long term (5+ years), structural transformation requires: sustained road network rehabilitation with climate-resilient design standards; institutional reform to establish functional quality grading and certification systems; and investment in vegetable processing capacity to reduce fresh market distribution pressure.

6.0 Research Gaps and the Way Forward

Existing literature reveals significant knowledge gaps that constrain evidence-based policy development for vegetable distribution in Nigerian urban centers. City-specific supply chain studies remain scarce, and most research provides regional or national-level insights that obscure local variations in distribution networks, loss patterns, and constraint profiles. Quantitative data on actual loss quantities, disaggregated by supply chain stage, vegetable type, and seasonal patterns, are limited, hampering the precise targeting of loss-reduction interventions.

Economic dimensions of informal distribution networks, including profit margins, transaction costs, and income distribution across supply chain actors, require deeper investigation to understand incentive structures driving current practices. Comparative studies examining distribution efficiency differences across Nigerian urban centres could identify best practices and context-specific success factors for replication. Gender and social equity dimensions of vegetable distribution remain understudied despite women's dominant participation.

Technology adoption studies to date have predominantly relied on cross-sectional surveys and case study designs that cannot establish causality or track behavioural change over time. Future research should prioritise: (1) longitudinal supply chain tracing studies that follow vegetable consignments through each distribution stage to identify precise loss points and their causes; (2) quasi-experimental or randomised impact evaluations of cold chain and digital platform interventions under Nigerian operational conditions; and (3) cost-benefit analyses of infrastructure investments that account for local maintenance capacity, electricity reliability, and trader income constraints.

Climate change vulnerability assessments of Nigerian vegetable supply chains are notably absent from the current literature. Future research should model the infrastructure exposure of key vegetable corridors under medium- and high-emission scenarios, assess the adaptive capacity of different supply chain actor groups (including smallholder farmers, women traders, and transporters), and develop resilience strategies that are costed and institutionally anchored.

7.0 Conclusion

This review demonstrates that vegetable transportation and distribution systems in Nigerian urban centres face substantial challenges rooted in infrastructure deficits, technological gaps, and institutional weaknesses. Transportation costs constituting 40–60% of retail prices and post-harvest losses ranging 30–60% reveal massive inefficiencies that most directly undermine two food security dimensions: availability, through physical and quality losses that reduce effective supply, and affordability, through cost mark-ups that price nutritious vegetables beyond the reach of low-income urban households. Stability and utilisation are also implicated through seasonal supply disruptions and the nutritional degradation of produce during extended transit.

Distribution networks remain predominantly informal with multi-layered intermediation, while cold chain infrastructure covers less than 10% of estimated requirements. Road network deterioration increases transit times and mechanical damage, particularly affecting highly perishable tomatoes and leafy vegetables. Emerging innovations, including mobile cold storage, digital market platforms, and cooperative aggregation, demonstrate promise for efficiency improvements, though scaling requires supportive policy environments, financing mechanisms, and investment mobilisation.

Policy imperatives should be sequenced by time horizon. Immediately, efforts should focus on improving practice, market information systems, and regulatory harmonisation. In the medium

term, cold chain node development at key wholesale markets and corridor road rehabilitation offer the highest returns. Structurally, long-term transformation requires institutional reform of market governance and quality grading systems, as well as the expansion of vegetable processing capacity. Throughout all horizons, gender-responsive design, ensuring that women traders' specific constraints and capacities are addressed, is not optional but essential to supply chain equity and efficiency. Emerging innovations, including mobile cold storage, digital market platforms, and cooperative aggregation, demonstrate promise for efficiency improvements, though scaling requires supportive policy environments and investment mobilisation.

Urban food security in Nigeria depends fundamentally on transforming vegetable distribution systems through coordinated infrastructure investment, technology adoption, stakeholder organisation, and supportive regulatory frameworks. Future research must provide city-specific evidence using longitudinal and quasi-experimental designs, quantify the economic dimensions of informal distribution systems, rigorously evaluate the impact and cost-effectiveness of proposed interventions, and assess climate vulnerability across key vegetable supply corridors, to guide effective, equitable, and resilient interventions in this critical food security domain.

References

Abass, A. B., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N., & Bekunda, M. (2014). Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. Journal of Stored Products Research, 57, 49–57.

Adeoye, G. O., Sanni, S. A., Fashola, O. S., & Balogun, R. B. (2009). Economic analysis of horticultural crop losses in the South-West of Nigeria. *African Journal of Biotechnology, 8*(16), 3848-3853.

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking postharvest losses in sub-Saharan Africa: A meta-analysis. World Development, 66, 49-68.

Ajiboye, A. O., & Afolayan, O. (2009). The impact of transportation on agricultural production in a developing country: A case of kolanut production in Nigeria. *International Journal of Agricultural Economics and Rural Development, 2*(2), 49-57.

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. *Journal of Economic Perspectives, 24*(3), 207-232.

Arah, I. K., Amaglo, H., Kumah, E. K., & Ofori, H. (2015). Preharvest and postharvest factors affecting the quality and shelf life of harvested tomatoes: A mini review. *International Journal of Agronomy, 2015*, Article 478041.

Aworh, O. C. (2008). The role of traditional food processing technologies in national development: The West African experience. In *Using Food Science and Technology to Improve Nutrition and Promote National Development* (pp. 1-18). Robertson Centre for Biostatistics, University of Glasgow.

Aworh, O. C. (2015). Promoting food security and enhancing Nigeria's small farmers' income through value-added processing of lesser-known and under-utilized indigenous fruits and vegetables. *Food Research International, 76*(3), 986-991.

Babalola, D. A., & Isitor, S. U. (2014). Analysis of the determinants of food expenditure patterns among urban households in Nigeria: Evidence from Lagos State. *IOSR Journal of Agriculture and Veterinary Science, 7*(5), 71-75.

Chijioke, O. C., Madu, T. U., & Agwu, A. E. (2020). Post-harvest losses of leafy vegetables in urban markets of Abuja, Nigeria: Causes and mitigation strategies. Journal of Agricultural Extension, 24(3), 44–56.

Babalola, D. A., Makinde, Y. O., Omonona, B. T., & Oyekanmi, M. O. (2010). Determinants of post-harvest losses in tomato production: A case study of Imeko Afon Local Government Area of Ogun State. *Acta SATECH, 3*(2), 14-18.

Balogun, O. L., Babatunde, O. M., & Esan, E. O. (2014). Assessment of transport infrastructure and distribution of agricultural products in Osun State, Nigeria. *Journal of Sustainable Development in Africa, 16*(5), 85-96.

Barrett, C. B. (2010). Smallholder market participation: Concepts and evidence from eastern and southern Africa. In *Food security in Africa*. Edward Elgar Publishing.

Cadilhon, J. J., Fearne, A. P., Moustier, P., & Poole, N. D. (2003). Modelling vegetable marketing systems in South East Asia: phenomenological insights from Vietnam. *Supply Chain Management: an international journal*, *8*(5), 427-441.

ColdHubs. (2022). *Annual Impact Report 2022*. ColdHubs Limited.

Dorosh, P., Wang, H. G., You, L., & Schmidt, E. (2012). Road connectivity, population, and crop production in Sub-Saharan Africa. *Agricultural Economics*, *43*(1), 89-103.

FAO. (2019). The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction. Food and Agriculture Organization of the United Nations.

FAOSTAT. (2023). *Food and Agriculture Organization Statistical Database*. Food and Agriculture Organization of the United Nations.

Federal Ministry of Agriculture and Rural Development [FMARD]. (2020). *National Agricultural Technology and Innovation Policy (NATIP) 2020-2030*. Federal Ministry of Agriculture and Rural Development, Nigeria.

Federal Ministry of Works. (2021). Federal roads condition survey report 2020–2021. Federal Republic of Nigeria.

Fentie, M. B., Goshu, D., & Tegegne, B. (2017). Determinants of potato marketed surplus among smallholder farmers in Banja District, Awi Zone of Amhara Region, Ethiopia. *International journal of agricultural Economics*, *2*(4), 129-134.

Idah, P. A., Ajisegiri, E. S., & Yisa, M. G. (2007). Fruits and vegetables handling and transportation in Nigeria. *AU Journal of Technology, 10*(3), 175-183.

Jacoby, H. G., & Minten, B. (2009). On measuring the benefits of lower transport costs. *Journal of Development Economics*, *89*(1), 28-38.

Jedermann, R., Nicometo, M., Uysal, I., & Lang, W. (2014). Reducing food losses by intelligent food logistics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 372*(2017), 20130302

Jedermann, R., Nicometo, M., Uysal, I., & Lang, W. (2014). Reducing food losses by intelligent food logistics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 372*(2017), 20130302.

Kader, A. A. (2013). Postharvest technology of horticultural crops-An overview from farm to fork. *Ethiopian Journal of Applied Science and Technology*, (1), 1-8.

Kehinde, A. D., Adeyemo, R., Oke, J. T. O., & Ogunleye, A. S. (2018). Effects of access to credit and membership in farmers' cooperatives on improved technologies adoption categories in cocoa-based farming systems of Southwestern Nigeria. *International Journal of Cooperatives Studies*, *7*(2), 22-29.

Kitinoja, L., & AlHassan, H. Y. (2012). Identification of appropriate postharvest technologies for improving market access and incomes for small horticultural farmers in Sub-Saharan Africa and South Asia. *Acta Horticulturae*, *934*, 31-40.

Kitinoja, L., & Kader, A. A. (2002). *Small-scale postharvest handling practices: a manual for horticultural crops*. Carlifonia: University of California, Davis, Postharvest Technology Research and Information Center.

Kitinoja, L., Saran, S., Roy, S. K., & Kader, A. A. (2011). Postharvest technology for developing countries: Challenges and opportunities in research, outreach and advocacy. *Journal of the Science of Food and Agriculture*, *91*(4), 597-603.

Mafimisebi, T. E. (2012). Spatial equilibrium, market integration and price exogeneity in dry fish marketing in Nigeria: A vector autoregressive (VAR) approach. *Journal of Economics and Sustainable Development*, *3*(8), 1-17.

Mercier, S., Villeneuve, S., Mondor, M., & Uysal, I. (2017). Time–temperature management along the food cold chain: A review of recent developments. *Comprehensive reviews in food science and food safety*, *16*(4), 647-667.

Mgbenka, R. N., Mbah, E. N., & Ezeano, C. I. (2016). A review of smallholder farming in Nigeria: Need for transformation. *International Journal of Agricultural Extension and Rural Development Studies*, *3*(2), 43-54.

Nwosu, C. A., Eze, P. N., & Obiora, C. F. (2023). Climate variability and agricultural supply chain disruptions in Nigeria's Middle Belt: Evidence from vegetable corridors. African Journal of Climate Change and Resource Sustainability, 6(1), 12–29.

Ogunkan, D. V. (Ed.). (2026). *Nigeria's Street Children: Lives and Dreams*. Taylor & Francis.

Oseni, T. O., & Masarirambi, M. T. (2011). Effect of climate change on maize (Zea mays) production and food security in Swaziland. *American-Eurasian Journal of Agricultural and Environmental Sciences*, *11*(3), 385-391.

Reardon, T., Barrett, C. B., Berdegué, J. A., & Swinnen, J. F. (2009). Agrifood industry transformation and small farmers in developing countries. *World development*, *37*(11), 1717-1727.

Reardon, T., Timmer, C. P., Barrett, C. B., & Berdegué, J. (2003). The rise of supermarkets in Africa, Asia, and Latin America. *American Journal of Agricultural Economics*, *85*(5), 1140-1146.

Ruel, M. T., Minot, N., & Smith, L. (2005). Patterns and determinants of fruit and vegetable consumption in sub-Saharan Africa: A multicountry comparison. *WHO Global Fruit and Vegetables Initiative Discussion Paper*.

Shukla, M., & Jharkharia, S. (2013). Agri-fresh produce supply chain management: a state-of-the-art literature review. *International Journal of Operations & Production Management*, *33*(2), 114-158.

Siddh, M. M., Soni, G., Jain, R., & Sharma, M. K. (2018). Structural model of perishable food supply chain quality (PFSCQ) to improve sustainable organizational performance. *Benchmarking: An International Journal*, *25*(7), 2272-2317

Tobin, D., Glenna, L., & Devaux, A. (2016). Pro-poor? Inclusion and exclusion in native potato value chains in the central highlands of Peru. *Journal of Rural Studies*, *46*, 71-80.

Umar, H. S., Agbonkpolor, B. N., & Jibrin, M. M. (2018). Analysis of postharvest losses and determinants of tomato marketed surplus among smallholder farmers in Kachia Local Government Area of Kaduna State, Nigeria. *Journal of Agricultural Economics, Environment and Social Sciences*, *4*(1), 52-63.

Van der Vorst, J. G. A. J., Da Silva, C., & Trienekens, J. (2007). *Agro-industrial supply chain management: concepts and applications*. FAO Agricultural Management, Marketing and Finance Occasional Paper 17, Food and Agriculture Organization.

Wan, X., & Li, C. (2022). Asymmetric price volatility transmission in agricultural supply chains: Evidence from the Chinese pork market. *Mathematical Problems in Engineering*, *2022*(1), 4801898.

Weinberger, K., & Lumpkin, T. A. (2007). Diversification into horticulture and poverty reduction: A research agenda. *World Development*, *35*(8), 1464-1480.