Assessing the Challenges Associated with Food Supply in West African Cities Through Performance Metrics and Supply Chain Techniques

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Abstract- ***This article explores the multifaceted challenges associated with food supply in West African cities, focusing on the impact of rapid urbanization, population growth, environmental factors, infrastructure deficiencies, and governance issues. The increasing demand for food in urban areas, coupled with the declining availability of agricultural land and reliance on food imports, has exacerbated food insecurity across the region. Key challenges include fragmented supply chains, inadequate transportation networks, insufficient storage facilities, and ineffective governance and regulatory frameworks. In addition, this article examines various solutions implemented to address these challenges, such as the promotion of urban agriculture, investment in infrastructure, and the adoption of advanced technologies like blockchain, IoT, and AI. Case studies from Lagos, Accra, and Dakar provide practical insights into the unique food supply challenges faced by these cities and the innovative solutions that have been implemented. The article also emphasizes the importance of measuring performance metrics, such as supply chain efficiency, resilience, and sustainability, to optimize food supply chains. Hence, the need for integrated approaches that combine infrastructure development, technology adoption, and governance reforms is highlighted. Continued research, innovation, and collaboration among governments, NGOs, the private sector, and local communities are critical for building resilient and sustainable food systems. The future of food supply in West African cities depends on the collective efforts of all stakeholders to address these complex challenges and ensure food security for the region's growing urban populations.***

I. INTRODUCTION

The food supply in West African cities faces significant challenges due to a combination of urbanization, climate change, infrastructure deficiencies, and socioeconomic disparities. Rapid urbanization in West Africa has led to an increase in food demand, while traditional agricultural systems struggle to keep up with this demand, leading to food insecurity in many urban areas (Drechsel et al., 2018). Over 58 million people in West Africa are underweight, with 22 million residing in urban areas, highlighting the urgent need for sustainable urban food systems (van Wesenbeeck, 2018). Furthermore, the COVID-19 pandemic has exacerbated these challenges, disrupting food supply chains and exposing the vulnerabilities of urban food systems in the region (El Bilali et al., 2023).

Food security in West Africa is deeply intertwined with sustainable urban food systems, which must be resilient to shocks and capable of providing sufficient, safe, and nutritious food to urban populations. Sustainable urban food systems are essential for ensuring that food is accessible and affordable to all, particularly in low-income urban areas where food insecurity is most acute (Tuomala and Grant, 2021). By addressing challenges such as rising food prices, limited farming resources, and poor infrastructure, and seizing opportunities like investing in agriculture and promoting urban farming, sustainable urban food systems can be developed to ensure food security in West African cities (Atuahene Djan, 2023).

The objective of this article is to assess the challenges associated with food supply in West African cities and explore the role of performance metrics and supply chain techniques in addressing these challenges. The article will provide a comprehensive analysis of the

key factors contributing to food supply issues in urban areas, including infrastructure deficiencies, supply chain inefficiencies, and policy and governance challenges. It will also examine the importance of performance metrics in measuring the effectiveness of food supply chains and propose supply chain techniques that can be used to improve food security in West African cities. The scope of the discussion will include case studies from major West African cities, such as Lagos, Accra, and Dakar, to provide practical examples of the challenges and solutions being implemented in the region.

II. BACKGROUND AND HISTORICAL CONTEXT

Urbanization in West Africa has significantly impacted food systems, altering the dynamics of food production, distribution, and consumption. The rapid expansion of urban areas has transformed cities into critical hubs for food distribution, where the magnitude and composition of food flows have changed, leading to longer supply chains and increased dependency on external food sources (Karg et al., 2022). This shift has intensified the pressure on food systems to meet the growing demand of urban populations, often resulting in food shortages and increased food prices (Kuhnlein and Johns, 2003).

The expansion of urban areas has also led to the conversion of agricultural land for urban development, reducing the availability of fertile land for food production (Gessner et al., 2016). This loss of agricultural land, coupled with the increasing demand for food, has further strained food systems in West Africa. As urbanization continues, the need for sustainable food systems that can support the growing urban populations becomes more critical (Igun et al., 2023).

Moreover, urbanization has contributed to dietary changes, particularly among urban dwellers, who are increasingly consuming processed and imported foods rather than locally produced staples. This dietary shift has implications for food security and nutrition, particularly for those living in poverty, as these foods are often less nutritious and more expensive (Kuhnlein and Johns, 2003). The impact of urbanization on food systems is further compounded by environmental challenges, such as climate change, which affects water availability and agricultural productivity in the region (Gessner et al., 2016).

Furthermore, poverty, population growth, and urbanization have a profound impact on food supply in West Africa, exacerbating the region's food security challenges. Rapid population growth, particularly in urban areas, has increased the demand for food, putting pressure on local agricultural systems that are often ill-equipped to meet this demand (Meerman and Cochrane, 1982). As urban populations expand, the availability of land for agriculture diminishes, leading to a reliance on imported food and the transformation of food consumption patterns towards more Westernized diets, which are often less nutritious and more expensive (Ag Bendech et al., 1996).

Poverty plays a critical role in limiting access to food, particularly in urban areas where the cost of living is higher. Poor households in West Africa often spend a large proportion of their income on food, and even small increases in food prices can push them into deeper food insecurity (Sanogo et al., 2022). This situation is further aggravated by the high levels of unemployment and underemployment in urban areas, which reduce the purchasing power of the population and limit their ability to access sufficient and nutritious food (Kourouma et al., 2022).

Urbanization has also led to significant environmental changes, such as the conversion of wooded savannahs into farmland and settlements, which, combined with the effects of climate change, further threaten food production in the region (Sanogo et al., 2022). The decline in per capita food production is also linked to poor agricultural performance, which is unable to keep pace with the rapid population growth and urban expansion (Oyinloye, 2015). The combined effects of poverty, population growth, and urbanization thus pose significant challenges to the food supply in West Africa, requiring comprehensive strategies that address these interconnected issues.

In addition, climate change and land degradation are significant environmental factors that directly impact food production and supply in West Africa. The region's agricultural systems are highly vulnerable to the adverse effects of climate change, which include

rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events (Defrance et al., 2020). These changes disrupt the growing seasons and reduce crop yields, exacerbating food insecurity in the region (Defrance et al., 2020). For example, local agricultural production in West Africa is projected to fall below 50 kg per capita by 2050 due to the combined pressures of climate change and population growth (Defrance et al., 2020).

Land degradation, which often results from unsustainable agricultural practices, deforestation, and overgrazing, further compounds the challenges posed by climate change. In West Africa, land degradation leads to the loss of arable land, reduced soil fertility, and increased vulnerability to erosion, all of which negatively impact food production (Roy et al., 2022). The expansion of agricultural land at the expense of natural ecosystems, driven by the need to meet growing food demand, has led to significant deforestation and degradation of land resources (Sanogo et al., 2022).

The impacts of climate change and land degradation are also closely linked to conflicts over natural resources. In many parts of West Africa, competition for land and water between farmers and herders has intensified as these resources become scarcer, leading to decreased food production and heightened food insecurity (Cabot, 2016). These conflicts underscore the need for sustainable land management practices and climate-smart agriculture to mitigate the impacts of environmental changes on food systems.

Adapting to these challenges requires the implementation of climate-smart agricultural practices that enhance the resilience of food production systems (Ouédraogo et al., 2019). Such practices include the use of drought-resistant crop varieties, improved soil and water management techniques, and the adoption of agroecological principles that promote biodiversity and sustainable land use (Ouédraogo et al., 2019). Without these interventions, the continued degradation of land and the worsening impacts of climate change will further threaten the region's food security.

III. CHALLENGES IN FOOD SUPPLY

Infrastructure Deficiencies

Infrastructure deficiencies, particularly poor transportation networks, inadequate storage facilities, and limited market access, are significant challenges that hinder food supply in West Africa. These issues disrupt the food supply chain, leading to food losses, increased costs, and reduced food availability, especially in rural and peri-urban areas (Obisesan, 2018; Akangbe et al., 2012; Sarpong and Nyanteng, 2002).

One of the major obstacles in West Africa's food supply chain is the poor transportation network (Obisesan, 2018). Many rural areas, where most agricultural production occurs, are connected to urban markets through inadequate road networks. This situation leads to delays in the transportation of food products, causing spoilage, especially for perishable goods like fruits and vegetables (Obisesan, 2018). The lack of efficient transportation infrastructure also increases the cost of food distribution, making food more expensive in urban markets and reducing the incomes of rural farmers who struggle to access these markets (Deissinger et al., 2015).

Inadequate storage facilities further exacerbate the challenges of food supply in West Africa. Many farmers lack access to proper storage technologies, resulting in significant post-harvest losses. For example, in the Asa Local Government Area of Kwara State, Nigeria, poor storage strategies such as the use of barns and indigenous plant materials have been identified as contributing factors to food insecurity (Akangbe et al., 2012). These losses are particularly severe during the harvest season when the lack of storage forces farmers to sell their produce at lower prices or risk spoilage. The absence of cold storage facilities also means that perishable goods cannot be stored for extended periods, limiting the ability to stabilize food prices throughout the year (Yiannas, 2016).

Limited market access is another critical issue affecting food supply in West Africa. Many small-scale farmers face challenges in accessing markets due to a combination of poor infrastructure and a lack of market information (Sarpong and Nyanteng, 2002).

This situation leads to inefficiencies in the food supply chain, as farmers may not be able to sell their produce at optimal prices or reach a broader consumer base. Market infrastructure, including transportation, storage, and price information systems, plays a vital role in facilitating cross-border food trade and improving food security in the region (Matsane and Oyekale, 2014).

To address these infrastructure deficiencies, investments in improving transportation networks, enhancing storage facilities, and expanding market access are essential. Efforts such as agri-logistics initiatives in Cote d'Ivoire have shown promise in reducing food losses and enhancing food security by improving the efficiency of supply chains (el Makhloufi et al., 2019). Additionally, interventions that connect small-scale farmers to markets, such as school feeding programs that source locally-produced food, can also improve market access and support rural economies (Zwane, 2015).

Supply Chain Inefficiencies

Supply chain inefficiencies are significant challenges facing the food supply system in West Africa, impacting both the availability and affordability of food products in the region (Sharma et al., 2023). These inefficiencies manifest in fragmented supply chains, a lack of technological integration, and logistical challenges, all of which contribute to increased food insecurity and economic instability (Sharma et al., 2023; Bilali et al., 2023). These issues are compounded by the vast geographical expanse and the underdeveloped infrastructure, which make the distribution of food products more complex and less efficient (Mohseni et al., 2023).

The fragmented nature of supply chains in West Africa is a major contributor to inefficiencies (Sharma et al., 2023). Supply chains in the region are often disjointed, with numerous intermediaries involved in the process, leading to increased costs and delays in the delivery of food products (Bilali et al., 2023). This fragmentation widens the gap between supply and demand, exacerbating food shortages and increasing prices for consumers (Sharma et al., 2023; Bilali et al., 2023). A study by Sharma et al. (2023) highlighted that the lack of monitoring systems within these fragmented chains further complicates the situation, making it difficult to track the movement of food commodities effectively (Sharma et al., 2023).

Another critical challenge is the lack of technological integration in the food supply chain (Subramanian et al., 2023). West Africa has been slow to adopt advanced technologies that could enhance efficiency and transparency (Sharma et al., 2023; Subramanian et al., 2023). For instance, the use of blockchain technology, which has been touted as a solution to improve traceability and accountability in supply chains, is still in its nascent stages in the region (Subramanian et al., 2023). Subramanian et al. (2023) argue that blockchain could address many of the transparency issues within the West African food supply chain by providing a tamper-proof digital ledger that records all transactions and movements of goods (Subramanian et al., 2023).

Logistical inefficiencies also play a significant role in hampering the food supply chain in West Africa (Mohseni et al., 2023; Hernandez-Cuellar, 2023). Poor road infrastructure, inadequate storage facilities, and inefficient transportation networks contribute to significant food losses and delays in getting food products to markets (Mohseni et al., 2023). These logistical challenges are exacerbated by the region's vulnerability to climate change, which affects crop yields and increases the unpredictability of food supplies (Hernandez-Cuellar, 2023). Mohseni et al. (2023) discuss the economic impact of these logistical inefficiencies, particularly in the transportation of refrigerated cargo between West Africa and Europe, where costs are inflated due to inefficient maritime supply chains (Mohseni et al., 2023).

The COVID-19 pandemic has also highlighted the weaknesses in West Africa's food supply chains (Bilali et al., 2023). The pandemic disrupted global supply chains, and the region's food systems were no exception (Bilali et al., 2023). A study by Bilali et al. (2023) shows that the pandemic's impacts further fragmented supply chains and worsened logistical inefficiencies, leading to significant challenges in ensuring food security (Bilali et al., 2023).

Thus, addressing supply chain inefficiencies in West Africa requires a multi-faceted approach (Sharma et al., 2023; Subramanian et al., 2023). This includes

investing in infrastructure, adopting advanced technologies like blockchain, and streamlining logistics to reduce food losses and improve market access (Subramanian et al., 2023; Mohseni et al., 2023). By addressing these challenges, the region can enhance its food security and build a more resilient food supply chain (Sharma et al., 2023).

Policy and Governance Issues

Inadequate policies, poor governance, and a lack of regulatory frameworks are significant challenges to food supply in West Africa. These issues create an environment where inefficiencies thrive, food security is compromised, and sustainable agricultural development is hindered. The absence of coherent policies and effective governance mechanisms in the region exacerbates the problems associated with food supply, making it difficult to address the root causes of food insecurity.

One of the key challenges is the lack of comprehensive and coordinated policies that address the complexities of food supply in West Africa. Many countries in the region have fragmented policies that do not align with the realities of the food supply chain. For example, policy gaps in the regulation of informal food markets, which are prevalent in urban areas, lead to inconsistencies in food quality and safety (Porter, Lyon, and Potts, 2007). These informal markets often operate outside the purview of formal governance structures, making it difficult to implement and enforce food safety regulations (Adeosun, Oosterveer, and Greene, 2023). The absence of effective policies to regulate these markets contributes to the persistence of food supply challenges in the region.

Poor governance further compounds the difficulties in ensuring a stable and efficient food supply. Governance failures manifest in various ways, including corruption, lack of accountability, and weak institutional capacities. These issues undermine efforts to improve food security and agricultural productivity. For instance, the inadequate governance structures in many West African countries have led to the mismanagement of resources allocated for agricultural development, resulting in suboptimal outcomes (Mwacalimba, 2016). The absence of transparent and accountable governance mechanisms also discourages investment in the agricultural sector, further exacerbating food supply challenges.

The lack of regulatory frameworks is another critical issue that hinders the effective management of food supply chains in West Africa. In many cases, existing regulations are outdated or poorly enforced, leading to inefficiencies in the supply chain. For example, the absence of a robust regulatory framework for the maize value chain in countries like Benin, Ghana, and Cote d'Ivoire has resulted in inefficiencies that limit the competitiveness of smallholder farmers (Ba, 2017). The lack of regulations to ensure fair trade practices and protect the interests of farmers and consumers creates an environment where food supply chains are vulnerable to exploitation and disruptions.

Addressing these policy and governance issues requires a multifaceted approach. Strengthening institutional capacities, improving transparency and accountability, and developing coherent and comprehensive policies are essential steps toward improving food supply in West Africa. Additionally, fostering collaboration between formal and informal sectors can help bridge the governance gaps that exist in the region's food supply chain (Adeosun, Oosterveer, and Greene, 2023). By addressing these challenges, West African countries can create a more resilient and efficient food supply system that supports food security and sustainable development.

- Performance Metrics in Food Supply Chains

Key Performance Indicators (KPIs) for Food Supply Chains

Key Performance Indicators (KPIs) are essential tools for measuring and monitoring the performance of food supply chains, as they provide insights into the efficiency, effectiveness, and sustainability of operations (Baba et al., 2019). In food supply chains, KPIs such as supply chain efficiency, lead times, and cost-effectiveness are particularly important for ensuring optimal performance (Marek et al., 2020).

Supply chain efficiency is a critical KPI that evaluates how well a supply chain converts inputs into outputs with minimal waste, optimizing resource utilization (Baba et al., 2019). This efficiency is crucial for reducing operational costs and improving overall performance, as efficient supply chains are better

equipped to handle disruptions and ensure timely delivery of food products to consumers (Baba et al., 2019).

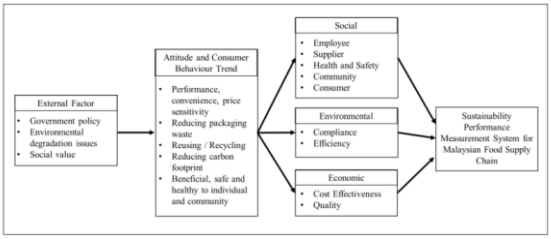

Fig. 1: Preliminary KPIs for Sustainable Performance Assessment in Malaysian Food Supply Chain (Baba et al., 2019)

The preliminary KPIs for assessing sustainable performance in the Malaysian food supply chain is illustrated in Fig. 1. It highlights how external factors such as government policy, environmental degradation, and social values influence consumer behavior trends, including performance, convenience, price sensitivity, and reducing waste. These consumer trends impact the social, environmental, and economic dimensions of sustainability (Baba et al., 2019). In the context of supply chain efficiency as a KPI, the focus is on ensuring environmental compliance and efficiency, as well as economic factors like cost-effectiveness and quality. These dimensions collectively contribute to a sustainability performance measurement system, aiming to enhance the overall efficiency and sustainability of the food supply chain in Malaysia (Baba et al., 2019).

Lead times, another vital KPI, measure the duration from the initiation of a process to its completion, which directly impacts product freshness and availability in food supply chains (Rattanachai et al., 2010). Shorter lead times are essential for ensuring that food products reach consumers quickly, reducing the risk of spoilage and maintaining high product quality (Rattanachai et al., 2010). In perishable food supply chains, minimizing lead times is particularly critical to avoid significant losses (Rattanachai et al., 2010).

Cost-effectiveness, a key financial KPI, assesses the balance between costs incurred and the value delivered by the supply chain, helping organizations determine the financial sustainability of their operations (Marek et al., 2020). In the context of food supply chains, cost-effectiveness is crucial for maintaining competitive pricing and ensuring that food products remain affordable for consumers, which is vital for both market competitiveness and food security (Marek et al., 2020).

Thus, KPIs such as supply chain efficiency, lead times, and cost-effectiveness are fundamental for managing and optimizing food supply chains. These metrics provide valuable insights that enable organizations to identify areas for improvement and enhance their overall operational effectiveness (Baba et al., 2019; Rattanachai et al., 2010; Marek et al., 2020).

Measuring Food Supply Chain Resilience

Assessing the resilience of food supply chains in the face of disruptions such as natural disasters and pandemics requires a multi-faceted approach, incorporating both qualitative and quantitative methods (Kumar et al., 2022). These methods focus on key resilience indicators, such as flexibility, adaptability, and redundancy, which are crucial for understanding how well a supply chain can absorb shocks and maintain functionality during and after disruptions (Kumar et al., 2022).

One widely used technique for measuring resilience is scenario planning, which involves simulating various disruption scenarios to evaluate the preparedness and response strategies of the supply chain (Mandal et al., 2023). Scenario planning is particularly effective in identifying potential weaknesses in the supply chain and developing contingency plans to mitigate the impact of such disruptions (Mandal et al., 2023). This approach is essential for food supply chains, where disruptions can have immediate and severe consequences on food availability and security (Mandal et al., 2023).

The use of resilience frameworks, such as the PESTLE framework (Political, Economic, Social, Technological, Legal, and Environmental), provides a structured approach to analyzing the factors that influence supply chain resilience (Lima, 2024). The PESTLE framework helps organizations assess risks from multiple perspectives and develop comprehensive strategies to enhance resilience (Lima, 2024). By integrating resilience into their strategic planning, organizations can better navigate the

complexities of disruptions and ensure continuity in their operations.

Technological innovation also plays a critical role in enhancing food supply chain resilience. The adoption of digital tools, such as real-time monitoring systems and predictive analytics, allows supply chains to quickly adapt to changing conditions and optimize their operations (Goel et al., 2024; Syed et al., 2024). These technologies provide valuable data that can be used to improve decision-making and reduce the vulnerability of the supply chain to external shocks (Goel et al., 2024).

Hence, measuring food supply chain resilience involves a combination of scenario planning, resilience frameworks, and technological innovations (Kumar et al., 2022; Lima, 2024; Mandal et al., 2023; Goel et al., 2024). These techniques enable organizations to assess their vulnerabilities and implement strategies to enhance their resilience, ensuring the continuity of food supply even in the face of significant disruptions (Kumar et al., 2022; Lima, 2024; Mandal et al., 2023; Goel et al., 2024).

Sustainability Metrics

Sustainability metrics are essential tools for assessing the environmental, social, and economic impacts of food supply chains. These metrics help organizations and policymakers understand the broader implications of their operations and guide decisions that promote long-term sustainability. Key environmental metrics include carbon footprint and energy use, which are crucial for evaluating the ecological impact of supply chains. Carbon footprint measures the total greenhouse gas emissions produced by a supply chain, providing insights into its contribution to climate change (Amirova and Ziganshin, 2023). Energy use, on the other hand, assesses the efficiency of energy consumption throughout the supply chain, helping to identify opportunities for reducing environmental impact (Rafiee et al., 2022).

Social sustainability metrics focus on labor conditions, which are critical for ensuring that supply chains operate ethically and support the well-being of workers. Labor conditions metrics assess factors such as wages, working hours, and occupational safety, ensuring that workers are treated fairly and that their rights are protected (Babych, 2018). These metrics are particularly important in food supply chains, where labor exploitation and unsafe working conditions can be prevalent.

Economic sustainability metrics evaluate the financial viability of supply chains, ensuring that they are not only environmentally and socially responsible but also economically sustainable. Metrics such as cost-effectiveness and profitability help organizations assess whether their operations can be maintained over the long term without compromising sustainability goals (Amirova and Ziganshin, 2023).

Therefore, sustainability metrics provide a comprehensive framework for assessing the environmental, social, and economic impacts of food supply chains. By measuring carbon footprint, energy use, labor conditions, and economic performance, organizations can identify areas for improvement and ensure that their supply chains contribute positively to sustainability goals (Amirova and Ziganshin, 2023; Rafiee et al., 2022; Babych, 2018).

Challenges in Implementing Performance Metrics

Implementing performance metrics in food supply chains is fraught with challenges, particularly concerning data availability, consistency, and accuracy. These challenges are critical because the effectiveness of performance metrics depends on the quality of data used (Kumar et al., 2017). Data availability is often limited in food supply chains, especially in developing regions, where digital infrastructure may not be as advanced. This lack of data can hinder the ability to track key metrics, such as inventory levels or transportation efficiency, leading to gaps in performance evaluation (Kim et al., 2023).

Consistency in data collection and reporting is another significant issue. In many food supply chains, data is collected from multiple sources, including farmers, processors, and distributors, each using different methods and technologies (Yensabai et al., 2023). This variability can lead to inconsistencies in the data, making it difficult to compare performance across the supply chain. For example, discrepancies in how data is recorded or the frequency of data updates can result in skewed performance metrics, reducing their reliability (Yan et al., 2012).

Accuracy is a fundamental challenge in implementing performance metrics. Inaccurate data can lead to incorrect conclusions about the performance of the supply chain, potentially resulting in poor decision-making (Shehu et al., 2024). Factors such as human error, outdated systems, or inadequate verification processes can compromise the accuracy of data, making it difficult to implement reliable performance metrics (Kaufman et al., 2014). To mitigate these issues, advanced technologies like blockchain and artificial intelligence are increasingly being adopted to improve data accuracy and traceability (Vinay et al., 2024).

- Supply Chain Techniques for Improving Food Supply

Supply Chain Techniques

Supply chain techniques such as lean supply chain management, just-in-time (JIT) delivery, and demand forecasting are critical for improving food supply chains, particularly in regions like West Africa. These techniques help enhance efficiency, reduce waste, and align supply with demand, which is essential for ensuring food security.

Lean supply chain management focuses on eliminating waste and optimizing processes across the supply chain. This approach emphasizes continuous improvement and operational stability, which are crucial for maintaining the efficiency and sustainability of food supply chains (Kerber and Dreckshage, 2011). By adopting lean principles, organizations can reduce costs, improve product quality, and enhance responsiveness to market demands (Marin et al., 2020). In West Africa, where supply chain inefficiencies can lead to significant food losses, lean supply chain management can play a vital role in minimizing waste and ensuring that food products reach consumers in a timely manner.

Just-in-time (JIT) delivery is another technique that can improve food supply chains by reducing inventory levels and minimizing the time between production and consumption. JIT delivery aligns production schedules with demand, ensuring that food products are produced and delivered only when needed, which reduces storage costs and minimizes the risk of spoilage (Scavarda et al., 2018). This technique is particularly beneficial in the food industry, where the freshness and quality of products are paramount (Roekel et al., 2002). In West Africa, JIT delivery can help address the challenges of limited storage infrastructure and reduce the reliance on large inventories, which are susceptible to spoilage and wastage.

Demand forecasting is another essential technique for improving food supply chains. Accurate demand forecasting allows organizations to predict consumer demand and adjust their production and distribution plans accordingly (Holimchayachotikul and Phanruangrong, 2009). This technique helps reduce the risk of overproduction or underproduction, ensuring that food supply meets demand without creating excess inventory or shortages (Holimchayachotikul et al., 2010). In West Africa, where market conditions can be volatile, effective demand forecasting can help stabilize food supply chains and ensure that food products are available when and where they are needed.

Technology Integration in Food Supply Chains

Technology integration plays a pivotal role in improving food supply chains by enhancing transparency, traceability, and efficiency. Blockchain, the Internet of Things (IoT), and Artificial Intelligence (AI) are among the most impactful technologies that can transform traditional food supply chains into more resilient and efficient systems (Hasan et al., 2023).

Blockchain technology significantly improves the traceability of food products throughout the supply chain. By providing a decentralized and immutable ledger, blockchain ensures that every transaction is recorded, enabling stakeholders to track the origin, journey, and quality of food products from farm to table (Goyal et al., 2023). This transparency builds trust between producers and consumers and helps mitigate issues related to food fraud and safety (Singh and Singh, 2020). For instance, in agricultural food supply chains, blockchain can reduce disputes by providing verifiable records of transactions, which is crucial for ensuring food security and compliance with standards (Bosona and Gebresenbet, 2023).

The IoT enhances supply chain management by enabling real-time monitoring and data collection across the supply chain. IoT devices, such as sensors

and RFID tags, can track environmental conditions, such as temperature and humidity, during transportation and storage, ensuring that food products are maintained at optimal conditions (Hasan et al., 2023). This capability is particularly important for perishable goods, where maintaining the cold chain is vital to preventing spoilage (Kumar et al., 2023). IoT also facilitates predictive maintenance of supply chain assets, reducing downtime and improving overall efficiency (Xiao et al., 2023).

AI further enhances the capabilities of food supply chains by enabling intelligent decision-making through data analytics and machine learning. AI can predict demand, optimize logistics, and improve inventory management, thereby reducing waste and ensuring that food products reach consumers efficiently (Vyas et al., 2022). AI-driven models can analyze vast amounts of data collected from IoT devices, providing insights that help supply chain managers make informed decisions that enhance performance and reduce costs (Kumar et al., 2023).

Thus, the integration of blockchain, IoT, and AI in food supply chains offers numerous benefits, including improved transparency, real-time monitoring, and intelligent decision-making. These technologies help address the challenges of traditional supply chains and pave the way for more sustainable and efficient food systems (Hasan et al., 2023; Goyal et al., 2023; Vyas et al., 2022).

Collaboration and Partnerships in Food Supply Chains
Collaboration among stakeholders, including governments, NGOs, and the private sector, is crucial for improving food supply chains. Effective partnerships foster innovation, enhance efficiency, and ensure that food supply chains are resilient and sustainable (Adinyira et al., 2010). One notable example of collaboration is the Partnership for Safe Poultry in Kenya (PSPK) Program, which demonstrated that public-private partnerships (PPPs) can significantly benefit smallholder farmers by improving production practices and increasing income levels (Knipscheer, 2019).

Governments play a vital role in creating regulatory frameworks and policies that facilitate collaboration among stakeholders. In Ghana's rural water sector, private sector-driven supply chains have improved outputs and services through government partnerships, highlighting the importance of government involvement in collaborative efforts (Adinyira et al., 2010). Similarly, international organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) work alongside governments and the private sector to enhance global food safety standards, demonstrating the impact of international collaboration (Eruaga, 2024).

NGOs are essential players in food supply chains, often acting as intermediaries between governments, private companies, and local communities. Their involvement ensures that the needs of vulnerable populations are addressed, and that supply chains are inclusive and equitable. For instance, NGOs can support smallholder farmers by providing technical assistance, facilitating market access, and advocating for policies that promote sustainable agricultural practices (Essien, 2016). In many cases, NGOs help bridge the gap between large-scale private sector initiatives and the grassroots level, ensuring that the benefits of collaboration reach those who need them most.

The private sector also plays a critical role in improving food supply chains through investments in infrastructure, technology, and capacity-building. Companies can drive innovation and efficiency in supply chains by adopting new technologies, such as blockchain and IoT, to enhance traceability and transparency (Itohan et al., 2023). Private sector financing can also contribute to building the resilience of food systems, particularly in the medium to long term, by investing in sustainable practices and infrastructure (CASA, 2023). However, it is essential that these investments are aligned with the broader goals of food security and sustainability, and that they are made in collaboration with other stakeholders.

Therefore, collaboration among governments, NGOs, and the private sector is essential for strengthening food supply chains. These stakeholders can create more resilient, efficient, and equitable supply chains that benefit all participants, from smallholder farmers to consumers by working together (Adinyira et al., 2010; Knipscheer, 2019; Eruaga, 2024). Such partnerships are crucial for addressing the complex

challenges of food security and ensuring that food supply chains are sustainable in the face of future disruptions.

Case Studies

Case Study 1: Lagos, Nigeria

Lagos, Nigeria, one of the fastest-growing megacities in Africa, faces significant challenges in food supply, exacerbated by rapid urbanization, population growth, and infrastructural limitations (Ogundele, 2020). The city's food supply chain is characterized by inefficiencies, including poor transportation networks, inadequate storage facilities, and inconsistent market access, leading to food insecurity and price volatility. Urban agriculture, though practiced in Lagos, remains largely uncoordinated, contributing little to the overall food supply due to lack of policy support and infrastructural investment (Akinmoladun and Adejumo, 2011).

One of the primary challenges in Lagos is the heavy reliance on food imports, which makes the city vulnerable to external shocks, such as global supply chain disruptions. This reliance has been further complicated by the COVID-19 pandemic, which disrupted both domestic and international food supply chains, leading to food shortages and increased prices in urban centers like Lagos (Adegboye et al., 2021). The concentration of food production in rural areas, combined with inadequate infrastructure for transporting food into the city, exacerbates food supply challenges. Additionally, informal food markets, which play a crucial role in feeding the urban population, operate with minimal regulatory oversight, raising concerns about food safety and quality (Adeosun, Oosterveer, and Greene, 2023).

To address these challenges, several initiatives have been implemented. One solution has been the promotion of urban agriculture as a means to increase local food production and reduce dependence on imports. Although still in its early stages, urban agriculture in Lagos shows promise as a supplementary source of fresh produce for the city's population (Babatunde et al., 2018). Furthermore, efforts to improve the governance of informal food markets through a combination of formal and informal regulatory structures have been undertaken to enhance food safety and market efficiency (Adeosun, Oosterveer, and Greene, 2023).

Another important solution is the development of infrastructure to support food storage and transportation. Investments in cold storage facilities and improved road networks are essential for reducing food losses and ensuring that food products reach urban markets in a timely manner. Additionally, digital platforms for coordinating logistics and market access have been explored to enhance the efficiency of food distribution within the city (Akazue et al., 2023).

Case Study 2: Accra, Ghana

Accra, the capital city of Ghana, faces significant food supply challenges driven by rapid urbanization, population growth, and infrastructural limitations. The city's food distribution system is characterized by inadequate infrastructure, poor waste management, and congestion in local markets, which hinder access to food for many residents (Ofori et al., 2022). Despite Ghana's diverse agro-ecological zones that allow for local food production, Accra remains heavily reliant on food imports, particularly for vegetables, further exacerbating food insecurity when global supply chains are disrupted (van Asselt, Masias, and Kolavalli, 2018).

The rise of supermarkets in Accra has also reshaped the city's food systems, influencing household food security. While supermarkets offer a range of food products, they often cater to wealthier segments of the population, leaving low-income households reliant on informal markets where food safety and quality may be compromised (Therien, 2017). This dual structure within the food system creates disparities in access to nutritious and affordable food, contributing to food insecurity in the city.

To address these challenges, various solutions have been implemented. One key intervention has been the development of transition pathways aimed at promoting healthier diets in Accra. These pathways focus on three main areas: maintaining cultural food practices, optimizing the food supply chain, and greening the city through urban agriculture (Linderhof et al., 2023). Urban agriculture, in particular, has been promoted as a sustainable solution to increase local food production and reduce reliance on imports,

although it faces challenges related to land availability and resource allocation (Linderhof et al., 2023).

Additionally, there have been efforts to improve the governance of the food system in Accra. The introduction of a comprehensive national food policy aims to streamline food distribution, reduce market congestion, and enhance food access for all residents (Ofori et al., 2022). This policy emphasizes the importance of infrastructure development, such as improved transportation networks and waste management systems, to support the efficient distribution of food within the city (Ofori et al., 2022).

Case Study 3: Dakar, Senegal

Dakar, Senegal, faces significant challenges in ensuring a stable and secure food supply due to a combination of rapid urbanization, limited agricultural space, and infrastructure deficiencies (Thiaw et al., 2020). Market gardening is a significant commercial activity in Dakar, particularly in urban and peri-urban areas like Ouakam, Parcelles Assainies, and Hann-Bel-Air. Despite its potential to contribute to food security, urban agriculture in Dakar is constrained by issues such as limited access to land, water scarcity, and inadequate support from government policies (Thiaw et al., 2020). This has led to food supply shortages, particularly for fresh vegetables, which are crucial for the city's population (Ba and Cantoreggi, 2018).

One of the critical challenges in Dakar's food supply chain is the dependence on food imports, particularly for high-value vegetables and staple grains. This reliance on imports makes the city vulnerable to external shocks, such as fluctuations in global food prices and disruptions in international supply chains (Seck and Thiam, 2022). Additionally, the high cost of importing food products, coupled with limited local production capacity, has resulted in food price inflation, further exacerbating food insecurity in the city (Maertens, 2006.

To address these challenges, various solutions have been implemented. Urban and peri-urban agriculture (UPA) has been promoted as a means to increase local food production and reduce reliance on imports. This approach focuses on enhancing the productivity of small-scale urban farmers by providing them with access to improved seeds, fertilizers, and training in sustainable farming practices (Ba and Cantoreggi, 2018). Furthermore, efforts to improve the distribution of essential nutrients, such as iron-folic acid supplements, have been undertaken to enhance food security and address malnutrition in vulnerable populations (Guèye et al., 2015).

Another promising solution is the promotion of organic agriculture in Dakar. Consumers in the city have shown a strong preference for organic vegetables, driven by concerns over health and environmental sustainability (Seck and Thiam, 2022). This has created opportunities for small-scale farmers to engage in organic farming, which not only improves food security but also supports sustainable agricultural practices.

- Policy Recommendations

Strengthening Infrastructure as a Policy Recommendation

Strengthening infrastructure, particularly in transportation and storage facilities, is critical for improving food supply chains and enhancing food security. Inadequate infrastructure is a significant barrier to efficient food distribution, leading to increased food losses, particularly for perishable goods (Todd and Narrod, 2006). To address these challenges, it is essential to invest in cold chain infrastructure, which includes refrigerated storage and transportation systems that maintain the quality and safety of food products from farm to market (Bharti and Sahay, 2020). Expanding cold storage facilities can significantly reduce food wastage, especially in regions with high temperatures, and support the growth of the food processing industry (Bharti and Sahay, 2020).

Improving transportation infrastructure is equally important. Efficient transportation networks reduce the time taken to move food products from production areas to markets, minimizing spoilage and ensuring timely delivery to consumers (Nguni, 2013). This is particularly crucial in regions where road networks are underdeveloped, and transportation delays are common. Investments in road construction and maintenance, as well as the development of efficient logistics systems, can help optimize food supply

chains and reduce overall costs (Mohamed et al., 2024).

Enhancing Governance and Regulatory Frameworks as a Policy Recommendation

Enhancing governance and regulatory frameworks is crucial for improving food supply chains. Effective governance requires clear, consistent, and enforceable policies that can adapt to the rapidly changing dynamics of global food systems (Ariane Voglhuber-Slavinsky et al., 2021). One approach to improving governance is to implement network-based risk analytics, which can help regulatory bodies identify and prioritize high-risk areas, thereby increasing the efficiency of food safety inspections by up to 42.1% (Levi et al., 2019). This approach enhances the ability of regulators to enforce standards effectively.

Another suggestion is the development of tailored regulations that consider the unique challenges faced by small food producers, as observed in European food supply chains. These regulations should be designed to support rather than hinder the operations of small-scale producers, thereby promoting inclusivity and sustainability in the food system (Živković et al., 2022). Additionally, governments should focus on responding to institutional pressures to improve food safety practices, as seen in the context of Lebanese food processors, ensuring that all stakeholders adhere to established standards (Abebe, 2020).

Promoting Technology Adoption as a Policy Recommendation

Encouraging technology use in food supply chains is essential for optimizing operations, improving transparency, and ensuring sustainability. Technologies such as blockchain, IoT, and AI can significantly enhance the efficiency and traceability of food supply chains, reducing waste and improving food safety (Itohan et al., 2023). For instance, blockchain technology can provide a decentralized and immutable ledger that tracks food products from farm to table, thereby enhancing transparency and building consumer trust (Zhang, 2024). IoT devices, such as sensors and RFID tags, enable real-time monitoring of environmental conditions during transportation and storage, ensuring that food products are maintained at optimal conditions (Hasan et al., 2023). AI, on the other hand, can predict demand, optimize logistics, and improve inventory management, helping to reduce waste and ensure that food products reach consumers efficiently (Vyas et al., 2022).

To promote technology adoption, policymakers should consider providing incentives such as tax breaks or subsidies for companies that invest in these technologies (Saha et al., 2023). Additionally, creating a supportive regulatory framework that addresses concerns related to data privacy and security can help overcome barriers to technology adoption (Dong et al., 2022). By encouraging the adoption of advanced technologies, governments can help build more resilient and sustainable food supply chains.

Building Collaborative Networks as a Policy Recommendation

Fostering partnerships among stakeholders in food supply chains is essential for improving efficiency, resilience, and sustainability. Collaborative networks enable diverse stakeholders, including governments, NGOs, and private sector entities, to pool resources and share knowledge, leading to more effective decision-making and problem-solving (Goel et al., 2024). These partnerships are particularly critical in addressing complex challenges, such as reducing food waste, enhancing food safety, and improving supply chain transparency (Sagi and Gokarn, 2022).

A key strategy for building collaborative networks is to establish formal structures, such as multi-stakeholder platforms, that facilitate ongoing dialogue and cooperation between different actors in the food supply chain (Rohenkohl do Canto et al., 2020). These platforms can help align the interests of various stakeholders and promote the adoption of eco-innovations that contribute to sustainable food systems (Rohenkohl do Canto et al., 2020). Additionally, social networking technologies can be leveraged to enhance communication and coordination across supply chains, making it easier for stakeholders to collaborate and respond to emerging challenges (Xu et al., 2014).

CONCLUSION

The food supply challenges in West African cities are deeply complex and interconnected, driven by rapid urbanization, population growth, environmental

factors, infrastructure deficiencies, and governance issues. This article has provided a comprehensive exploration of these challenges while examining the strategies and solutions that have been employed to mitigate them. Historically, urbanization in West Africa has reshaped food systems, positioning cities as central hubs for food distribution but also intensifying food security concerns. The rapid urban expansion has strained agricultural resources, lengthened supply chains, and increased dependency on food imports. These dynamics underscore the urgent need for sustainable urban food systems that can meet the demands of growing urban populations.

Poverty, population growth, and urbanization have exerted significant pressure on food supply systems. In urban areas, poverty restricts access to food, while population growth escalates demand, further stretching limited agricultural resources. Urbanization, despite its potential for economic advancement, has led to dietary changes and environmental degradation, exacerbating food supply issues. Environmental challenges, particularly those related to climate change and land degradation, have further complicated food production and supply in the region. West Africa's agricultural systems are particularly vulnerable to these factors, which disrupt planting cycles, diminish yields, and spark resource conflicts. To combat these challenges, climate-smart agricultural practices and sustainable land management are essential.

Infrastructure deficiencies, particularly in transportation, storage, and market access, continue to be major impediments to efficient food supply chains. These deficiencies lead to significant food losses, higher costs, and limited availability, particularly in rural and peri-urban regions. Investing in infrastructure, such as cold storage facilities, improved transportation networks, and digital logistics platforms, is crucial for strengthening food security. At the same time, inefficiencies in supply chains, often caused by fragmentation, inadequate technology, and logistical challenges, further disrupt food supply in West Africa. These inefficiencies result in delays, increased costs, and limited traceability of food products. Improving supply chain coordination, adopting technology, and optimizing logistics are vital steps toward ensuring that food reaches consumers effectively.

Policy and governance issues, including weak regulatory frameworks and inadequate policy implementation, continue to hinder progress in addressing food supply challenges. Strengthening governance, developing coherent policies, and fostering collaboration between formal and informal sectors are key to improving food security in the region. Key performance indicators (KPIs) such as supply chain efficiency, lead times, and cost-effectiveness play a crucial role in managing and optimizing food supply chains. Regular monitoring of these KPIs helps organizations identify areas for improvement and enhance their operational performance.

Furthermore, resilience in food supply chains is critical, particularly in the face of disruptions such as natural disasters and pandemics. Techniques like scenario planning, resilience frameworks, and technological innovations help organizations assess vulnerabilities and implement strategies to strengthen their resilience. Sustainability metrics, including carbon footprint, energy use, and labor conditions, are essential for evaluating the environmental, social, and economic impacts of food supply chains. Achieving sustainability in food systems requires a balanced approach that integrates economic, social, and environmental considerations.

In this article, case studies from major West African cities such as Lagos, Accra, and Dakar have demonstrated the unique challenges and innovative solutions tailored to each city's context. These examples highlight the potential for targeted interventions and localized strategies to improve food supply systems in the region. By synthesizing these insights, this article underscores the need for a multi-faceted approach that addresses the myriad challenges facing food supply in West Africa's rapidly urbanizing cities.

The way forward for improving food supply in West African cities lies in adopting integrated approaches that combine infrastructure development, technology adoption, and governance reforms. An integrated approach ensures that food supply challenges are

addressed holistically, with consideration given to the interconnected nature of these issues. For example, improving transportation infrastructure not only enhances food distribution but also supports market access and reduces food losses. Similarly, adopting digital technologies can improve supply chain efficiency, enhance traceability, and enable better decision-making.

Continued research and innovation are also critical to the future of food supply in West Africa. Ongoing research into climate-smart agriculture, sustainable food systems, and supply chain optimization will provide valuable insights and solutions that can be scaled across the region. Innovation in areas such as urban agriculture, renewable energy, and digital platforms will also play a crucial role in addressing food supply challenges.

Collaboration among stakeholders, including governments, NGOs, the private sector, and local communities, is essential for building resilient and sustainable food systems. Partnerships that foster knowledge sharing, resource pooling, and joint problem-solving will be key to overcoming the complex challenges of food supply in West African cities.

The future of food supply in West African cities is at a critical juncture. With rapid urbanization and population growth showing no signs of slowing, the pressure on food systems will continue to increase. However, with the right strategies and investments, it is possible to build food supply chains that are resilient, efficient, and sustainable.

The success of these efforts will depend on the collective action of all stakeholders. Governments must take the lead in creating enabling environments for innovation and investment, while the private sector must drive technological advancements and infrastructure development. NGOs and community organizations must continue to advocate for the needs of vulnerable populations, ensuring that food supply systems are inclusive and equitable.

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