DIGITAL SUPPLY CHAIN OPTIMIZATION AND NUTRITIONAL FOOD SECURITY FOR FRESH PRODUCE IN NAIROBI COUNTY: A CASE STUDY OF KIBRA SUB-COUNTY

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A RESEARCH PROJECT SUBMITTED TO THE SCHOOL OF MANAGEMENT AND LEADERSHIP IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF BUSINESS ADMINISTRATION OF THE MANAGEMENT UNIVERSITY OF AFRICA.

APRIL 2025

DECLARATION

I declare that this research project is my original work and has not previously in its entirety or in part been presented for a degree or other academic work.

Signature: _________________________ **Date: _________________________**

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This project has been presented for examination with my approval as the appointed supervisor.

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DEDICATION

This research project is dedicated to my old man, Caleb Ingolo for seeing in me what I fail to see in myself sometimes, potential, greatness and for being my accountability partner on this academic journey, my best friend Gideon Kipkemoi for allowing me to pick his brain every once in a while, and showing up for me whenever, and my friends for immense support, encouragement and prayers in the course of my studies.

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My sincere appreciation goes out to our Almighty God, for His grace and guidance through my academic pursuit, to my supervisor, Dr. Derow Aden, for his guidance and insightful criticism throughout my research process, and to the management and staff of the Management University of Africa for their continuous support.

ABSTRACT

Kenya's fresh produce supply chain faces significant challenges, including poor market access, inefficiencies in distribution, and high food loss rates, all of which impact food security and nutrition. This research investigated digital supply chain optimization on food security and nutritional outcomes within Kenya's fresh produce sector. The specific objectives of the study included determining the impact of digital logistics integration, assessing the effects of digital market linkages, and evaluating digital traceability and information sharing's influence on nutritional food security. The study was grounded under four theories with systems theory being the anchor theory supported by supply chain management integration theory, resource-based view theory, technology acceptance model theory and food security framework. A cross-sectional research approach was used, targeting a study population of 398 respondents obtained using a stratified random sampling technique to ensure representativeness across the different segments. Through qualitative and quantitative methods, including interviews with stakeholders, this research determined the efficacy of digital supply chain technologies in mitigating food security and nutrition challenges and enhancing access to nutritious fresh produce. Data gathered was analyzed using statistical techniques, including descriptive and regression analysis to determine the relationship between digital supply chain optimization indices and food security and nutrition indicators. Qualitative data was analyzed using content analysis while quantitative data was coded and analysed using SPSS version 28 respectively. Data collected was entered into a spreadsheet for summarization and from which relevant tables and figures were populated for presentation. Ethical considerations were also observed during the study. A pilot study was conducted using 40 participants to refine the survey instruments and 319 respondents participated in the survey. The findings revealed that digital logistics integration had the strongest positive impact ($\beta = 0.65$, $p < 0.001$), explaining 42.3% of variance in nutritional food security through improved delivery efficiency and reduced post-harvest losses. Digital market linkages showed significant influence ($\beta = 0.60$, $p < 0.001$), facilitated by mobile platforms like Twiga Foods, Wasoko, Taimba and M-Pesa, though adoption was constrained by low digital literacy (30%) and unreliable internet (45%). Digital traceability systems (e.g., blockchain, IoT) had limited adoption (3.1–4.7%) due to infrastructural barriers, while digital transparency enhanced decision-making but lacked regulatory frameworks. The study concluded that digital supply chain technologies collectively explained 67.2% of nutritional food security variance ($R^2 = 0.672$), with affordability and accessibility remaining critical challenges. Recommendations included investing in community Wi-Fi hubs, low-technology traceability solutions (SMS-based systems), and digital literacy programs tailored to Kibra's low-income population. The research contributed to policy and practice by highlighting scalable interventions to bridge supply chain gaps in urban informal settlements, aligning with SDG 2 (Zero Hunger) and Kenya's Food and Nutrition Security Policy. Further investigation is warranted in light of the study's results, recommendations, and conclusion. This additional research should aim to corroborate other factors that were not examined in this study and offer fresh information to validate the current findings.

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ABBREVIATIONS AND ACRONYMS

AU:	African Union
CAK:	Communications Authority of Kenya
FAO:	Food and Agriculture Organization
FDA:	Food and Drug Administration
FNSP:	Food and Nutrition Security Policy
GDP:	Gross Domestic Product
KDHS:	Kenya Demographic and Health Survey
KNMS:	Kenya National Micro-Nutrient Survey
MOH:	Ministry of Health
NCDs:	Non-communicable Diseases
UN:	United Nations
UNEP:	United Nations Environment Programs
SDGs:	Sustainable Development Goals
SPSS:	Statistical Package for Social Sciences

OPERATIONAL DEFINITION OF TERMS

Digital supply chain optimization	Strategic use of digital technologies and data analytics to improve efficiency, visibility, agility, effectiveness and responsiveness of the supply chain operations.
Digital market linkages	Use of technology like online platforms and mobile applications to connect producers with consumers, facilitating the flow of goods, services, information and capital and ultimately improving market access and efficiency.
Digital logistics integration	Use of digital technologies in the logistics processes to improve efficiency, transparency, visibility and collaboration within the supply chain.
Digital traceability	Use of digital technology to track a product as it moves along the supply chain
Digital transparency	Degree to which companies openly share information that impacts stakeholder decisions, transparency in instrumental in fostering trust and loyalty (Portes et al.,2020)
Nutritional food security	This exists when all people, all times have a continued physical and economic access to sufficient, nutritious and safe foods that meet their dietary requirements, enabling them to lead an active and healthy life. (FAO, 2017).

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter focuses on the background information of this study, with a description of each study variable and how their relation is in accordance with the entire study. The section also looks into the statement of the problem, research questions, objectives of the study, and a justification for the significance of the study. It concludes by highlighting the scope of the research study.

1.1 Background of The Study

As defined by the Food and Agriculture Organization (FAO), food security is the availability, accessibility, utilisation, and stability of food that provides the nutritional requirements and personal choices of people aiming to maintain an active and healthy way of life. Food and nutrition security is key to achieving both human and economic development (FNSP, 2017). According to FAO's sustainable development goals (SDGs), zero hunger is listed as the second focal area of concern. The rampant rise of food insecurity has been attributed to several factors, including inefficiencies in food systems and high food prices (FAO et al., 2017). The SDGs' main goal is to be able to feed the population through a sustainable environmental method, which will involve the transformation of the food and agricultural systems, among other factors (FAO, 2017).

Complex nutrition challenges are also being faced worldwide. Different forms of malnutrition, such as obesity, overweight, micronutrient deficiency and undernutrition are present everywhere, in countries, households and amongst individuals (WHO,2017). An estimate of 2 billion people are affected with micronutrient deficiency globally and 200 million children are stunted or wasted (Committee on World Food Security,2016). Diet is important to a population and most people globally consume highly unhealthy foods instead of fruits and vegetables which are nutritious (Willet et al, 2019). This occurs due to several factors which include, but are not limited to inadequate access to nutritious food, increasing incomes and urbanization. Because of these, food systems around the world are in need of interventions such as digital technologies. The Kenya Demographic and Health Survey (KDHS, 2020) reports that 1.8 million children (29%) suffer from undernutrition. The national per capita energy intake per day is less than what is recommended (Gitu, 2004). The inefficiencies in the fresh produce supply chain contribute to this issue by limiting access to affordable, diverse, and nutritious food. Improving the distribution of fresh produce through digital technology can enhance the nutritional intake of the population and contribute to better health outcomes across the country.

Despite the high increase in the amount of food being produced across the globe, and particularly in Kenya, that is enough to cater for the entire population, an estimated one billion people are reported to sleep hungry (CGIAR, 2011). A few indicators have been developed and are widely used in the analysis of food security. They include dimensions (stability, availability, utilisation, and accessibility), components (quality, safety, quantity) and levels (individuals, regional, global).

Several policies and manifestos have been developed in relation to curbing food nutrition and insecurity and in conjunction with the UN SDGs, such as the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods (AU, 2014). Its agendas include creating a drive for boosting the increase in agricultural practices in different regions and offering support during implementation phases and enhancing financial investments in the agricultural sector through budgetary allocations and friendly policies. It is also committed to ending hunger by 2025 through ensuring there is sustainable and reliable food production processes, minimal post-harvest losses and free trading area of agricultural products and services.

In Kenya, achieving nutritional food security remains an ongoing challenge because of inefficiencies in the agricultural supply chain, particularly for fresh fruits and vegetables and low use of agricultural technology. Over 10 million people suffer from chronic food insecurity and poor nutrition, and between 2 and 4 million individuals need emergency food assistance (Republic of Kenya, 2018). The agricultural sector is the backbone of the Kenya's economy and contributes to over 26% of the gross domestic product (GDP), over 50% of the country's export (PSC, 2018) and employing approximately 70% of the rural population (World Bank, 2021). The sector enjoys attention from the government as it promotes its national development by contributing 45% to the government revenue (KARI, 2009).

Agriculture is a mode of life for a good number of the population. Fresh fruits and vegetables are significant to the national diet and are vital for nutrition. Nonetheless, shortcomings within the supply chain, including high losses post-harvesting, limited and poor market access for farmers, fluctuating food prices, and logistical challenges, result in significant food wastage and reduced ease of access to nutritious food, thus diminishing the efforts to combat malnutrition and food insecurity. Technologies have evolved and are now acting as fuels for transforming the agricultural value chain, giving innovative solutions to optimize supply chain operations and enhance food security (World bank, 2020).

A key issue in Kenya's fresh produce supply chain is post-harvest losses. As a result of inadequate infrastructure, limited cold storage, and inefficient transportation systems, up to 40% of fresh produce is lost before it reaches consumers (FAO, 2019). The lack of an efficient cold chain system exacerbates the challenge, as fruits and vegetables are highly perishable and require prompt transportation in order to maintain their freshness and nutritional value. Smallholder farmers, who account for most of Kenya's fresh produce, often face significant barriers in accessing formal markets, leading them to sell at lower prices to intermediaries or in informal markets (Chibanda et al., 2019). These barriers contribute to high levels of food insecurity, especially among those from low-income urban and rural households, where nutritious food is often out of reach due to high prices and supply chain inefficiencies.

Fresh produce supply chain in Kenya is characterised by several interrelated challenges that hinder its effectiveness. These challenges range from infrastructural deficits and market fragmentation to the involvement of multiple intermediaries, all of which contribute to high losses and inflated prices. The challenges include;

Infrastructural deficits, particularly poorly done rural transportation networks, restricting farmers' ability to reach markets and transport their goods from production to urban consumption areas. Majority of rural roads are impassable during the rainy season, leading to delays and spoilage of perishable goods. The lack of cold storage facilities compounds this problem, as fresh produce needs to be stored in temperature-controlled environments to maintain freshness (Harris et al., 2020). Without proper storage, much of the produce is lost before it can be sold.

Fragmented distribution networks where the fresh produce supply chain in Kenya is highly fragmented, involving multiple actors, such as farmers, intermediaries, transporters, wholesalers, and retailers. Each intermediary adds a margin to the final price of the product, which inflates costs for consumers and reduces profits for farmers (Kaminski &

Christiansen, 2014). Furthermore, this system leads to delays in getting produce to market, thus reducing its quality and nutritional value by the time it reaches the consumer.

Post-harvest losses, which are characterised by high levels of food waste, are a major issue in Kenya's fresh produce supply chain. According to FAO, up to 40% of fruits and vegetables are lost post-harvest because of inadequate handling, poor storage, and delays in transportation (FAO, 2019). These losses not only reduce the availability of nutritious food but also negatively impact farmers' incomes, contributing to rural poverty. Addressing the losses post harvesting is critical as it enhances food security and improves the sustainability of the agricultural sector.

Market access barriers for smallholder farmers, producing the majority of Kenya's fresh produce, face significant challenges in accessing formal markets. Many rely on intermediaries to sell their products, often at lower prices than they would receive in formal markets. Additionally, farmers lack access to timely market information, which tampers with their ability to make informed decisions about when and where to sell their produce (Kamau et al., 2021). Scarce financial resources also hinder farmers from investing in improved technologies or transportation systems, further hindering their market access.

The inefficiencies within the supply chain result in higher food prices for consumers, more so in urban areas, where access to the fresh produce is often scarce. For low-income households, the cost of fresh produce is prohibitively high, leading to poor dietary choices and contributing to malnutrition. Addressing the systemic challenges in the supply chain is essential in efforts to improve nutritional food security in Kenya.

1.1.1 Digital Logistics Integration

As stated by Christopher,2016 digital logistics integration can be defined as the use of digital technologies in streamlining logistics operations, that boost supply chain transparency and increase overall effectiveness. It enables real-time tracking, automated inventory management and predictive analysis in order to optimize transportation and warehousing (Gligor et al., 2019). Emerging technologies such as Internet of Things and blockchain play a crucial role in digital logistics integration by improving delivery accuracy, enhancing traceability and reducing lead time (Wang et al, 2020). Digital logistics integration has been found to have a possibility of minimizing post-harvest losses, enhancing food safety and ensuring timely distribution of fresh produce (Kamble et al.,2021).

Nutritional food security is a critical issue in Kenya, where inefficient supply chain management contributes to significant post-harvest losses, reduced access to fresh produce and price volatility. According to FAO, 2022, post-harvest losses in Kenya's fresh produce sector range from 30-50%, largely due to inefficient logistics and poor cold infrastructure. Digital logistics integration can play a transformative role in addressing these challenges by improving transportation efficiency, ensuring real-time monitoring of perishable goods and enhancing market linkages for smallholder farmers (Njuki et al.,2023).

Digital traceability systems that are blockchain-enabled can enhance food safety by ensuring compliance with quality standards, reducing risks of contamination and improving customer confidence (Kamble et al.,2021). AI-driven demand forecasting tools can help stabilize market prices, ensuring fresh produce reaches consumers in time, therefore improving food availability and nutrition (Mukherjee& Signh,2022). Digital platforms that integrate logistics with e-commerce solutions can also bridge the gap between farmers ad consumers, minimizing dependency on middlemen and increasing access to affordable and nutritious food (Wang et al.,2020).

In the context of Kenya, several digital logistics initiatives have emerged such as mobile-based aggregation and GPS-enabled fleet management solutions, which have improved efficiency in the fresh produce supply chain. Gaps, however, still remain in the infrastructure sector, policy support and digital literacy among stakeholders. Addressing these barriers through investing in smart logistics, enhanced collaboration between stakeholders, and supportive policies by the government can enhance food security and nutrition outcomes in Kibra sub-county.

1.1.2 Digital Market Linkages

Digital market linkage is the use of online platforms and digital tools to link farmers, wholesalers and consumers, thus facilitating efficient trade (Njuki et al.,2023). Through these linkages, access to markets is enhanced thus providing farmers with direct connections to buyers, reducing dependency on middlemen and mitigating the volatility of prices. E-commerce platforms, mobile applications and digital payment solutions play a key role in improving the efficiency of transactions and market transparency (Mukherjee &singh,2022). By integrating these digital market platforms with reliable data analytics, fresh produce supply chain can achieve smooth coordination, improved market forecasting and enhanced financial inclusion for farmers (FAO, 2022).

The impact on nutritional food security by digital market linkages is quite substantial. By limiting the reliance on traditional market structures, these digital platforms allow farmers to trade their produce at generally fair prices whilst ensuring timely access to the fresh and nutritious produce for consumers (FAO, 2022). Digital platforms enable smallholder farmers to access real-time market information, lessening food losses occurring due to surplus production or poor demand forecasting. Enhanced market transparency through these linkages helps stabilize prices, making fresh produce more affordable for low-income populations (Mukherjee &singh,2022). There is also an aspect of efficient and sustainable food distribution networks where online trading platforms facilitate bulk purchasing and streamlined logistics coordination, ensuring perishable goods reach the market faster, reducing spoilage and improving food availability (Kamble et al.,2021). Additionally, digital financing solutions integrated into market linkages provide farmers with secure payment options, reducing financial risks and enabling investment in sustainable agricultural practices (Wang et al.,2020).

In Kenya, expansion of digital market linkages has significantly contributed to the improvement of nutritional food security. However, challenges such as limited internet connectivity, inadequate regulatory support and resistance to digital adoption have hindered the full realization of these benefits (FAO,2022). Addressing these gaps through investment in digital infrastructure, policy frameworks and capacity-building initiatives can further enhance the role of digital market linkages in promoting nutritional food securiy for fresh produce in Kibra sub-county.

1.1.3 Digital Traceability and Information Sharing

Digital traceability and information sharing involve the use of advanced digital tools and platforms to track, record and disseminate data regarding food production, processing and distribution (Kumar & Brint,2023). These systems enhance supply chain visibility by providing real-time data on product movement, quality and safety. Technologies such as blockchain, IoT sensors and cloud databases play an important role in ensuring transparency, reducing fraud and minimizing food loss in the supply chain (FAO, 2021). Integrating digital traceability solutions with data analytics, fresh produce supply chains can have enhanced coordination, improved decision making and supported sustainable farming practices (Perez et al.,2023).

Digital traceability and information sharing's impact on nutritional food security is significant as it has ensured timely access to fresh, safe and high-quality food for consumers (World Bank, 2021). Smallholder farmers make the most from better market access as they can showcase the quality of their produce to buyers through digital records, reducing the role of middlemen and increasing their income (UNCTAD,2022). It also helps stabilize market prices, making fresh produce inexpensive and reducing food insecurity risks (Gomes et al.,2021).

Digital traceability and information-sharing initiatives have improved nutritional food security by enhancing market efficiency, reducing losses and ensuring food safety. These challenges, however, hinder the widespread adoption due to several factors such as execution costs, and limited technical know-how. Addressing these factors can potentially enhance the role of digital traceability and information sharing in securing nutritional food security in Kibra sub-county.

1.1.4 Nutritional Food Security in Kenya

Food security, as stated by the UN Committee, is known to exist when at all times, all the people, have reliable physical and financial access to sufficient, safe and nutritious food to support individuals in meeting their nutritional requirements and food preferences to maintain an active and healthy life. Nutritional food security comprises of food accessibility by people through their power to purchase in markets and its availability through production, storage, or transportation. Kenya's food security landscape is complex, marked by the coexistence of under-nutrition and rising levels of diet-related non-communicable diseases, examples being obesity and diabetes. Rural populations face high levels of food insecurity, which arise from the inefficiencies in the fresh produce supply chain. The reliance on smallholder farmers, coupled with poor infrastructure and market fragmentation, limits the availability of fresh produce, leading to nutritional deficiencies among vulnerable groups.

According to the KDHS (2020) and KNMS (2011), malnutrition remains a significant public health issue, with 26% of children under five suffering from stunting, which depicts chronic undernourishment with counties like Kitui and West Pokot leading at 46%, Kilifi, Narok, Uasin Gishu, Tharaka Nithi at 31-39% and Baringo, Nandi, Kericho and Nairobi following at 26-30%. Women also fall into this category of undernourishment at 11%. This is linked to the 50% of Kenyans falling below the line of poverty and amongst those living in extreme poverty. Some of these are individuals in relatively well-endowed urban and rural areas (NFNSP, 2017).

Urban areas are also not immune to nutritional food insecurity, as the high cost of fresh produce often forces low-income households to rely on cheaper, less nutritious processed foods. This shift in dietary patterns has contributed to an increase in NCDs such as obesity, diabetes, heart problems and other related health issues, particularly in Kenya’s rapidly growing cities. Improving the efficiency of the fresh produce supply chain is crucial for ensuring that all Kenyans, regardless of income level, have access to affordable, nutritious food (MOH, 2017).

The potential of online technologies to improve food security in Kenya is significant. By streamlining the processes in the supply chain, reducing losses post-harvesting, and facilitating better market opportunities for small-scale farmers, these technologies can help increase the availability of fresh produce and lower its cost. This can improve nutrition and other health outcomes for many individuals, especially those considered as vulnerable groups in communities. Furthermore, transparency provided by digital platforms can help consumers make healthier dietary choices by ensuring that they purchase food that is fresh and of high quality.

1.1.5 Kibra Sub- County and Food Security

Kibra, has overtime grown into a densely populated urban slum area due to rapid rural-urban migration (Mutisya et al., 2011). Its key characteristics include geographic and administrative context which looks at its location, demographic profile which looks at it’s population that recorded 185,340 residents (KDHS, 2020) and its socio-economic conditions which is characterized by substandard housing, limited access to clean water, and sanitation.

Food security has been a pressing issue in Kibra, because of poverty, unemployment and urban vulnerabilities which exacerbate hunger. Several studies have been done and the findings showed that the prevalence and pattern of food insecurity in Kibra affected a good number of individuals (Murage et al., 2014). Surveys done linked low income and unemployment to hunger, with residents often consuming affordable staples to “subdue hunger” rather than for nutrition (WFP, 2022).

The studies also limited access to clean water and sanitation increases food safety risks, such as typhoid from contaminated sources (UN Habitat, 2020). Dietary diversity is low, with reliance on staples like maize and limited access to nutrient rich foods like vegetables and fruits due to high costs (FAO, 2022). A 2020 survey in Kibra and similar slums (Mukuru, Dandora) found low-income households face poorer access to nutritious foods, contributing to stunting (17.6% nationally, higher in slums), anemia (21.9% in women), and obesity (28% in adults) from unbalanced diets (KNBS, 2020).

Contributing factors to this challenge has been limited access to clean water and sanitation which in turn has increased food safety risks, such as typhoid from contaminated sources (UN Habitat, 2020). Dietary diversity has also been low, with reliance on staples like maize and limited access to nutrient-rich foods like fruits and vegetables (FAO, 2022). A 2020 survey in Kibra and similar slums (Mukuru, Dandora) found low-income households faced poorer access to nutritious foods, contributing to stunting (17.6% nationally, higher in slums), anemia (21.9% in women), and obesity (28% in adults) from unbalanced diets (Murage et al., 2020).

Digital interventions, such as mobile logistics platforms, therefore aim to improve supply chain efficiency but faces barriers. Areas feeding Kibra and sources of fruits and vegetables lack reliable internet (World Bank, 2023), and low digital literacy among farmers (15% use digital tools; FAO, 2022) thus hindering adoption. High technology costs and mistrust among supply chain actors has further complicated the coordination (GSMA, 2023).

1.2 Statement of The Problem

Nutritional food security remains to be identified as a major concern for slum urban areas of Nairobi, despite the many food security initiatives being done. Several developmental agencies and the government have invested resources to address the concerns on food security through programs and projects, with minimal success being achieved.

Approximately 16% of Kibra households experience food insecurity, with limited access to fresh produce which are essential for combating malnutrition, particularly among children and low-income families (Wanyama et al.,2023). This contributes to high rates of micronutrient deficiencies, stunting and related health issues (FAO, 2021). The reliance on informal markets like Toi, coupled with inefficient supply chains, exacerbates these challenges, making nutritious food scarce, unaffordable and often unsafe.

Inefficiencies in the fresh produce supply chain, characterized by significant post-harvest losses of upto 40% due to poor logistics, limited market access for smallholder farmers, lack of traceability for quality assurance and inadequate transparency in pricing hinder the availability, accessibility, quality and stability of nutritious produce (Onwude et al.,2023). Low adoption of these technologies further promotes these issues (Gitonga et al.,2010), for instance in April 2018, Nairobi County was hit by a severe shortage of tomatoes, which resulted in high prices. Ironically, tonnes of tomatoes were rotting away in farms in Uasin Gishu County. Farmers attributed this to exploitation by intermediaries who were buying the tomatoes at lower prices and their inability to access the markets to sell off their produce (Letting, 2018).

To address this, the study proposes an investigation to evaluate how digital supply chain optimization, through the study variables, that is digital logistics integration, digital market linkages, digital traceability and transparency can enhance nutritional food security in Kibra. By collecting data from the 398 respondents across the stakeholders, the study aims to identify effective digital interventions and provide actionable recommendations for stakeholders and policy makers to improve food security outcomes in Kibra's informal markets. This research will bridge the gap in Kibra specific studies, offering evidence-based solutions to a pressing local and national challenge.

1.3 General Objective

The main objective of the research was to assess the relationship between digital supply chain optimization and nutritional food security outcomes within the Kenyan fresh produce sector.

1.3.1 Specific Objectives

i. To determine the impact of digital logistics integration on nutritional food security in Kibra sub-county.
ii. To assess the effect of digital market linkages on nutritional food security in Kibra sub-county.
iii. To evaluate how digital traceability influences nutritional food security in Kibra sub-county.
iv. To determine how digital transparency and information sharing affects nutritional food security in Kibra sub-county.

1.4 Research questions

i. What is the impact of digital logistics integration on nutritional food security and in Kibra sub-county?
ii. How do digital market linkages affect nutritional food security in Kibra sub-county?
iii. To what extent does digital traceability influence nutritional food security in Kibra sub-county?
iv. How does digital transparency and information sharing affect nutritional food security in Kibra sub-county?

1.5 Significance of Study

Optimization of digital supply chain is important for enhancing the nutritional food security in Kenya, as it faces significance challenges, particularly in accessing fresh produce, because of the inefficiencies in the supply chain. Smallholder farmers, who produce a big percentage of fresh fruits and vegetables, experience high post-harvest losses of up to 40% because of poor infrastructure, inadequate market access, and limited cold storage (FAO, 2019). These inefficiencies waste valuable food and inflate prices, making fresh produce unaffordable for many low-income households. Digital supply chain technologies therefore showed potential of providing an avenue of solutions through real-time tracking, demand forecasting and enhanced market accessibility.

This research study provided important insights for policymakers, supply chain and agricultural stakeholders as it helped in developing frameworks for integrating digital tools in food supply chains and creating regulations that promote transparency, data sharing and public-private partnerships to ensure access to nutritious food. It also provided empirical evidence, highlighting the transformative role of digitizing supply chain to reduce food wastage, improve logistics efficiency and ensure availability of the fresh fruits and vegetables.

The conclusions drawn illuminated insights into the necessary investment and policy interventions required to boost the acceptance of digital technologies in Kenya’s fresh produce sector, ultimately improving nutritional food security outcomes as well as opening a new interdisciplinary avenue for researchers in logistics, technology, public health and agricultural economics for further academic exploration

1.6 Scope of The Study

The scope of the study focused on a sample of 398 stakeholders, limited to Kibra sub-county, which is characterized by high density, informal markets like Toi and infrastructure challenges. It also focused on the fresh produce involving stakeholders like digital platform providers, logistics providers, market vendors, consumers, farmers and policy entities. The general concern of the study looked into the use of digital logistic platforms, digital markets linkages, digital traceability systems and digital traceability platforms within the fresh produce supply chain. The study assessed the impact of these technologies on the reduction of losses post-harvesting, improvement of nutritional diversity and affordability of fresh produce. Cross-sectional method of approach was made use of, integrating qualitative and quantitative data analysis to evaluate the effectiveness of digital supply chain solutions in improving nutritional food security. The study run from January 2025 to September 2025.

1.7 Chapter Summary

This chapter introduced a detailed background to the study with a detailed meaning of the assessment of online technologies and a brief description of other variables and the way they may impact nutritional food security in Kenya. The chapter also conceptualised the other variables in the research project and exposed them to the problem the study aimed to solve. The chapter also introduced the objectives, justification, significance, and scope of the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter investigates the theoretical literature and empirical literature with the aim of creating a good understanding on digital supply chain optimization and nutritional food security for fresh produce. It has covered studies published in various sources, such as reviewed journals, newspapers, publications and online databases to identify what has already been done and gaps identified for purposes of the research. It also looked at the empirical literature review, summary of the chapter, the conceptual framework, research gaps and operationalization of study variables.

2.1 Theoretical Literature Review

Turner et al., (2018) stated that theoretical review focuses on the explanation of the relationship between ideas or theoretical underpinnings which inform the study. It focuses on the interconnectedness among the variables being looked at in the study in relation to the statement of the problem through elaboration and analysis as these theories. It helps in understanding, forecasting and detailing circumstances as well as expounding on already existing knowledge. This literature review aids in elaborating why a research topic under study occurs. Appropriate theories have been applied and the research has been grounded under four theories, including supply chain management theory, resource-based view theory,

2.1.1 Systems Theory

Systems theory, originally developed by Ludwig Bertalanffy in 1968 conceptualizes a supply chain as a complex, interdependent system made up of various components that must work together harmoniously to achieve efficiency, responsiveness and overall functionality. The theory posits that changes in one part of a system will inevitably affect the others. Applied to the fresh produce supply chain, this means any digital intervention, such as a mobile logistics platform, traceability systems, including production practices, market access, pricing, consumer choice and ultimately, food availability and nutritional outcomes.

This theory's relevance is evident as Nairobi's fresh produce supply chain involves multiple actors, i.e., farmers, wholesalers, logistics providers, consumers, technologies such as mobile apps and external forces such as policies and infrastructure. Through viewing this chain as a dynamic system, the theory allows for exploration of how digital innovations introduced at any point such as e-commerce for urban consumers can propagate benefits and disruptions throughout the system. This system-based perspective is therefore critical to understanding how technology not only improves logistical efficiency but also enhances food safety, reducing losses and increasing access to diverse and nutritious foods, particularly for vulnerable urban populations.

Systems theory also integrates well with and provides a foundation for other supporting theories through focusing on the firm-level digital capabilities within the broader supply chain system, emphasizing the role of digital platforms in reducing inefficiencies within the system, explaining how innovations spread across the different parts of the systems and looking at the flow of data within the systems.

2.1.2 Technology Acceptance Model Theory

Developed by Fred Davis in 1989, the technology acceptance model theory explains how users accept and use technology and, it posits that two key factors influence an individual's decision to adopt the specific technology which is perceived ease of use (how effortless individuals find the system to operate), and perceived usefulness (the extent to which a person believes that using a particular system enhances their performance). The two key factors are important in coming up with effective digital systems, especially for optimizing supply chains and ensuring food security in the fresh produce sector.

The adoption of advanced technologies in supply chains can transform how fresh produce is managed and distributed. Using the technology acceptance model, stakeholders in the supply chain can identify the barriers to technology acceptance and improve systems as needed. For instance, digital tools like blockchain and Internet of Things have led to improved traceability and transparency as they have provided secure records at every stage of the supply chain which has been beneficial for ensuring the quality of fresh produce and devices that monitor different conditions thus reducing spoilage rates respectively. Studies indicate that enhancing the two key factors directly correlates to increased adoption of digital solutions (Davis 1989; Venkahtesh and Bala, 2018).

This theory also offers insight into promoting technology adoption to addressing food security and nutritional challenges. In the context of fresh produce, technology can help in cutting down on food waste and guaranteeing equal access to nutritious food by improving distribution efficiency. An example of this technology is predictive analysis which looks at past data and market insights to forecast demand for fresh produce, streamline supply chain and minimize waste. Consumer education on the benefits and safety of these technologies is however paramount as it can positively influence their perceived usefulness and ease of use (M. McCormack et al.,2022).

2.1.3 Supply Chain Management Integration Theory

The theory on supply chain integration emphasises on the importance of seamless coordination between supply chain actors, which includes producers, processors, distributors, and retailers (Keith Oliver, 1982). This coordination aims to improve efficiency, reduce costs, and enhance product quality (Flynn et al., 2010). The theory argues that the high levels of integration are in conjunction with better performances in the supply chain, including reduced inventory levels and improved customer satisfaction.

In Kenya's fresh produce sector, where smallholder farmers dominate, supply chain integration is crucial for limiting losses post-harvesting, maximising efficiency and ensuring timely delivery of perishable products as the integration of these online technologies has facilitated leaner supply chains (lean supply chain management) (Leither et al., 2019). Digital platforms facilitate the integration by improving communication through information sharing, enabling tracking of goods in real-time, lowering transportation costs through optimising logistics and improving demand forecasting through data analytics (Kamau et al., 2021). By reducing time taken to get produce from farm to market, digital technologies support the alignment of supply and demand, leading to reduced spoilage and better market access for farmers.

Agricultural supply chains are vulnerable to various disruptions. The theory of supply chain management offers a structure for building systems that can withstand and recover from these disruptions and digital tools are a key part. With the focus being on food security and nutrition, the theory provides a framework to analyze how digital optimization can increase the availability of nutritious food, improve accessibility for vulnerable populations and enhance the stability of food supply.

2.1.4 Resource-Based View Theory

Barney, 1991 initialized the resource-based theory, which explains that an organisation can achieve a competitive advantage through leveraging unique capabilities and resources. In this context, of digital supply chain optimization, organizations investing in blockchain for traceability, IoT-enabled logistics and demand forecasting driven by AI can strengthen their supply resilience and efficiency in operations.

Access to real-time data in the fresh produce supply chain enhances decision-making for farmers and retailers, leading to better demand forecasting and reduced post-harvest losses (Ksherti,2018). There's also an aspect of blockchain-based traceability which enhances food safety compliance and consumer trust by providing transparent records of food origins and quality (Moe,2019). Digital infrastructure has lower supply chain costs and better inventory management, reducing waste and improving profitability (Teece et al.,2017). Automation of warehousing and logistics as a form of digital supply chain optimization can lead to an improvement in efficiency and a reduction in operational bottlenecks, ensuring fresh produce reaches markets in optimal condition (Wamba et.al.,2020).

Resource-based view theory underscores the role of digital capabilities as strategic assets that enable organizations to gain a competitive edge in fresh produce supply chains. Companies that leverage these technologies effectively, enhance food security by improving efficiency and reducing food loss. Twiga Foods, for instance, connects farmers directly with urban markets through retailing, whereby they have established an online website platform that enables the registration of producers and suppliers and acts as the link between the different groups. The company aggregates produce from the farmers, transports to the warehouse for quality and safety checks, and then sorts it before delivering it to the clients. This model has enhanced the local "mama mboga" market by acting as the link between the farmers and retailers (Twiga Foods, 2019)

2.1.5 Food Security Framework

The concept of food security has progressed throughout the years since the first introduction of the term to the policy context in the early 1970s. There have been several attempts to define it as is evident in the existing literature (Clay, 2003; Maxwell, 1996; Tansey, 2013). In the preceding years, food security has been understood to rest on four key pillars: food availability, food accessibility, food utilisation and food stability (CFS, 2009; FAO, 2006; Upton et al., 2016; Webb et al., 2006;).

Following the crisis that occurred in 2007-2008, the four pillars framework became a canon within the UN Committee on World Food Security and FAO. This framework provided a theoretical basis for understanding how improvements in the fresh produce supply chain could enhance food security. Food availability pertains to the ample production and efficient food supply, food access is the economic and physical ability of people to acquire it, food utilisation involves the consumption of food that meets the nutritional needs, while food stability refers to consistent access to food over a period.

Digital supply chain optimization can enhance all the four food security dimensions by improving the efficiency and transparency of the supply chains. For example, digital platforms that connect smallholder farmers directly to markets can improve food availability by reducing losses post-harvesting (Kamau et al., 2021). Increased accessibility to the market information empowers farmers to further negotiate for better prices, hence improving their economic access to food. Improved digital supply chain efficiency additionally reduces food prices for consumers, thus enhancing physical access to nutritious produce (Barrett, 2015).

The FAO’s food security framework is critical for assessing the potential of digital technologies to address food insecurity in Kenya (FAO, 2017). By focusing on the entirety of a food system, from production to consumption, this framework helps identify how digital supply chain improvements can lead to better nutritional outcomes for both rural and urban populations.

2.2 Empirical Literature Review

This section’s literature review examined the various research studies that have been conducted on digital supply chain optimization and food security and nutrition for fresh produce. As much as there have been several studies conducted, research gaps exist which the current study identified and tried to provide potential solutions.

2.2.1 Digital Supply Chain Optimization

Digital supply chain optimization is defined as the application of digital technologies strategically, to improve visibility, efficiency, sustainability and responsiveness of operations occurring in the supply chain across the board, from production all the way to consumption. This has been conceptualized in Kenya’s fresh produce as a solution to the inefficiencies in the system that hinder access to nutritious food, particularly in low-income urban areas like Kibra sub-county.

Several elements are encompassed in the digital supply chain optimization which include digital logistics integration that leverages tools such as automated routing to reduce transit time and produce spoilage (Kamau et al.,2021); digital market linkages that use e-commerce, such as wasoko, Taimba and Twiga foods, to link farmers directly to retailers and consumers, hence bypassing intermediaries (Twiga Foods,2019), digital traceability that includes mobile apps and blockchains which enhance food safety and trust within consumers by enabling real time monitoring of the produce(Kshetri,2018) and information sharing and transparency that further supports decision making across the supply chain by facilitating accurate and timely data among the stakeholders(Wamba et al.,2020).

These technologies are important as they aid in reducing food losses, logistics costs and empowering smallholder farmers with market insights and market prices, thereby enhancing food availability, accessibility and utilization, which are the key pillars of food security (FAO,2017). It also plays a crucial role in improving nutritional outcomes and food security by looking at both supply and demand challenges in the fresh produce ecosystem.

2.2.2 Digital Logistics Integration and Nutritional Food Security

The food production sector in Kenya has been constantly evolving over the years. The food supply chain has been influenced by several factors, such as the perishability of the produce, safety, and costs involved (Garcia-Flores et al., 2015). Digital logistics integration, hence, entails a structured process that facilitates optimization of supply chain efficiency, reduced wastage of fresh produce on the farm, and increased profit margins for the stakeholders to enhance access to nutritious food. Through leveraging technologies such as real-time tracking, blockchain and artificial intelligence, digital logistics improve the visibility and coordination of food supply chains, ensuring timely and efficient food distribution.

Research on the impact of technology adoption in enhancing food security in Kenya was done by Karari (2019). The research used descriptive study to examine the role of technology adoption with its main targets being farmers. The research findings were that digital technology improved traceability, enhanced access to transport service providers, and strengthened connectivity among farmers. This contributed to more efficient logistics and distribution of fresh produce. This study provided insights into technology adoption but did not specifically focus on the digital logistics of fresh produce.

The presence of efficient logistics system in Kenya enables the reduction of transaction costs, less wastage of produce on the farm and increased profits for the stakeholders involved. Transportation requires cooperation between the farmers, transporters, and traders, which then helps in enhancing communication between the stakeholders. Farmers are informed on the collection points to take their produce for aggregation by the transporters and traders for sale in urban areas (Wajszczuk, 2017). Requirements by organisations such as the FDA for the food logistics sector include transportation vehicles and equipment that are well maintained, cleaned and maintain proper temperatures for safe food transportation, thus promoting food nutrition and security, especially the fresh produce.

Effects of Just in time deliveries and demand forecasting on a food organization company as conducted by Mutua et al (2021) using a casual research design and utilizing questionnaires to collect data, with a target population of 83 departmental heads showed that its implementation had a beneficial influence on the overall performance of the organization as those who were driven by AI analytics and big data, helped in predicting market demand, thus allowing for more precise planning of production and distribution. This ensured that fresh produce was supplied in optimal quantities, hence reducing losses and improving food availability. Kenyan startups have increasingly leveraged predictive analytics to match supply with demand, improving access to markets for the smallholder farmers and therefore ensuring food security in urban areas.

According to a publication done by Dr. Kitinoja, (2014) the main focus was on the setbacks and opportunities linked with coming up with cold chain systems to lessen post-harvest losses in the sub-Saharan Africa. The study targeted Stakeholders within the agricultural value chain such as farmers, traders and policymakers, using a qualitative research design. It was found that post-harvest losses were quite significant in perishable goods due to inadequate cold chain infrastructure, thus leading to decreased availability of food and economic losses for farmers. There being lack of proper investment in refrigerated transportation and, cold chain facilities contributed to the inefficiencies in the fresh produce supply chain. The study underscored the adoption of cold chain management which was to be embraced as it ensured cold temperatures are maintained as the fresh produce is handled from harvest down to the market till it reaches the consumer, as handling of fresh produce at suboptimal temperatures aggravates deterioration from the biological agents.

Low-cost alternatives suited for rural areas and slummy areas of Nairobi have also been researched on such as off-grid evaporating cooling technologies and solar-powered cold storage, such as JuaBaridi and Freshbox (Lal Basediya et al., 2013). Although these technologies have proven effective in the preservation of post-harvest fresh fruits and vegetables, their adoption rate however, is very low.

2.2.3 Digital Market Linkages and Nutritional Food Security

Digital market linkages have emerged as a transformative tool in reducing inefficiencies in food supply chains, enhancing transparency in the market sector and reducing inefficiencies in the food supply chains thus improving food security and nutrition. These digital platforms, ranging from e-commerce marketplaces, block chain-enabled supply chains and mobile-based agricultural platforms close the gap between farmers and consumers, leading to better market access, price fairness and reduced food waste.

In 2023, Smith et al conducted a research study on the role of digital market linkages in enhancing food security in the rural population of Kenya, with a target population of 500 smallholder farmers while employing a mixed method approach of research data collection, combining surveys and case studies. The study found that mobile-based market linkages improved price transparency and reduced costs on transactions, allowing farmers to have access to larger markets and secure better prices for their produce. Consumers also benefited, as there was an increase in access to fresh produce at competitive prices.

Adebayo et al (2021) conducted research in E-Commerce and food access focusing on the impact of online marketplaces on Nutrition in urban Kenya. The study had a sample size of 800 urban households and utilized quantitative surveys and purchasing power behaviour as the mode of research method. The finding showed that e-commerce platforms improved access to diverse food options, particularly among consumers from the working class who had limited time for traditional market shopping.

In 2015, Olwande conducted a study titled Agricultural Marketing by Smallholder Farmers. The study's target population consisted of smallholder farmers in Kenya, using descriptive surveys. The study found that efficient markets promoted quick distribution of agricultural and food products from areas of surplus to those of deficits. Smallholder farmers, especially those in Kenya, faced numerous setbacks in accessing markets, including limited information, high costs of transportation, and dependency on intermediaries. The intermediaries scouted for produce from the farmers in the production areas, then transported them to retailers in open-air markets or companies involved in food processing. Because of the inability of most farmers to access markets individually, most were forced to sell their fresh produce at throwaway prices.

Studies such as that conducted by Aker and Mbiti (2015), which encompassed a broad demographic landscape of sub-Saharan Africa as the target population and a comprehensive literature review methodology, looking at data from various sources, and another conducted in Tanzania by Msuya,(2020) using cross-sectional survey, collecting data from farmers through structured questionnaires to assess the impact of mobile phone usage on market access, indicated that there had been a drastic increase in mobile phone coverage and adoption in many countries. The studies found that digital technologies addressed these challenges by providing farmers with direct access to buyers and market information. For instance, mobile phones and digital platforms improved farmers' access to markets by providing real-time price information, enabling them to make better-informed decisions about the optimal timing and location for selling their produce.

2.2.4 Digital Traceability and Nutritional Food Security

Digital traceability is the use of technology to monitor and verify the movement, safety and quality of food products throughout the supply chain. Technologies such as blockchain and the Internet of Things have been leveraged to improve food safety and enhance consumer confidence among many other things. Digital traceability plays a key role in ensuring food security and nutrition by preventing food contamination, reducing waste and ensuring fair trade practices.

Mwakio et al (2023) conducted research on blockchain technology and food safety focusing on the fresh produce supply chain in Kenya with a sample size of 350 smallholder farmers, retailers and consumers. A case study approach and qualitative interviews were used. The study found that the adoption of blockchain-based traceability systems reduced instances of food contamination by 30% and improved customer trust in fresh produce. Additionally, blockchain-enabled tracking improved price transparency, allowing farmers to receive fair prices for their produce.

A research study on IoT-based food traceability systems, conducted by Wang and Patel (2022), found a resulting impact on food security, with a sample size of 500 supply chain stakeholders, including farmers, logistics providers and retailers and quantitative analysis of IoT-enabled traceability systems in food supply chains as a research methodology. The study found that IoT-based sensors enhanced real-time monitoring of food products, thus reducing spoilage rates by 25%. Improved traceability also minimized fraud activities, such as mislabelling and food adulteration. The study pinpointed their being lack of regulatory frameworks to govern IoT implementations in food supply chains, emphasizing the need for policies to standardize digital traceability solutions.

QR Code-based traceability and consumer Nutritional choices as conducted by Ahmed et al (2021), with 1200 consumers in urban markets and surveys and experimental design as research methods, found that it positively influenced consumer purchasing decisions, leading to higher demand for nutritious and organic foods. Consumers who accessed product traceability information were 40% more likely to choose fresh produce over process alternatives. The study also found that while urban consumers benefited from this traceability system, rural populations had limited access due to poor digital divide issues.

2.2.5 Digital Transparency, Information Sharing and Nutritional Food Security

Digital transparency and information sharing are pivotal in transforming the current modern supply chains, particularly in sectors dealing with perishable goods such as fresh produce. It refers to use of digital technologies to provide real time, accessible and accurate data across all stages of the supply chain, from farm to fork. This includes tracking and tracing goods, performance metrics and inventory visibility whereas information sharing looks into seamless exchange of data between supply chain actors to enhance decision-making, foster trust and reduce uncertainties.

In 2020, Nyange conducted a research study in Kenya and Tanzania on market information and food security, with a target population of 500 smallholder farmers using a mixed method approach, including surveys and focus group discussions and found that farmers with access to real-time market prices information through digital platforms were able to make better decisions on where and when to sell their produce, thus resulting in increased incomes and improved household food security. Nyange also highlighted that market transparency reduced food price volatility, benefiting both farmers and consumers.

Jones and Smith (2021) also did research on transparency in agricultural markets and the effects on food security with a sample size of 1200 households in Ethiopia. Quantitative analysis was used using household income and food consumption surveys. It was found that there existed a positive correlation between market transparency and household food security. Households with access to transparent market data had better diversity in terms of their dietary choices and were less likely to experience seasonal food shortages. Market transparency was also linked to increased investment in local food production

In a study done by Ahmed et al (2022), on food price volatility and transparency in global markets, which utilized an analysis of 10 years of global food market data with econometric modelling and time series analysis as the research methods, it was found that countries with very high levels of market transparency experienced lower levels of food price volatility. These transparent markets enabled better coordination amongst the stakeholders in the food supply chain, hence leading to more stable food prices and improved food security outcomes. The study's main focus was on the macroeconomic trends.

Tadesse and Bahiigwa (2015) conducted a study in Ethiopia on mobile phones and farmers' marketing decisions, with a targeted population of 1023 households. The study utilized a descriptive research design, gathering data through questionnaires. The study showed that digital supply chain optimization technologies had helped reduce the asymmetry of information in the markets by reducing the reliance on intermediaries by farmers, who would control access to information. Producers in rural areas were then able to gain access to regional markets. Inaccurate information given by the intermediaries back in the day would result in farmers underselling their produce, excess, or underproduction of produce, or spoilage during harvest.

2.3 Summary and Research Gaps

This chapter included an examination of the already existing literature on the evaluation of the impact of online technologies in addressing the supply chain challenges for fresh produce to enhance nutritional food security to help in a thorough understanding of the previous research findings, which are linked to the objectives of the study. These reviews helped in the identification of several knowledge gaps, as shown in the table.

Table 1: Research Gaps

Author and year	Title	Methodology	Findings	Research gaps	Focus of current study
Munyua, H., and Mwakaje, A. (2017)	Impact of ICT in agricultural supply chains in Kenya	Descriptive analysis	ICT tools like mobile apps and e-commerce platforms improved communication and coordination between farmers and markets.	Limited focus on the specific digital technologies in reducing losses and promoting food security.	This research focuses on investigating the role of digital supply chains specifically in bridging gaps for fresh produce to enhance food security and nutrition.

Author and year	Title	Methodology	Findings	Research gaps	Focus of current study
Owuor.,2018	The state of household food security in Nairobi Kenya	Survey of 1434 households	70% of households experience food insecurity, informal markets are vital for fresh produce.	Limited exploration of supply chain factors affecting food security	This research underlines the importance of efficient supply chains in addressing food insecurity
Adhiambo and Osoro (2023)	Supply chain scalability and performance on large food processors in Nairobi City County	Descriptive analysis with 192 staff	Supply chain integration and diversified supply base significantly improves performance	No specific focus on fresh produce or nutritional outcomes	This research looks into assessing how digital supply chains bridge gaps, specifically for fresh produce, focusing on improving nutritional food security.
Abate, G.T., Abay, k.a., Chamberlin, j., & Kassim, Y. (2023)	Digital tools and agricultural market transformation in Africa	Literature review of conceptual and empirical studies	Digital tools have potential to transform agricultural markets by improving information sharing, reducing transaction costs and enhancing market access	Limited understanding of factors hindering the scaling of digital tools, need for more nuanced evidence from both successful and unsuccessful scaling efforts, lack of integration between digital tools and existing market structures.	This research looks to investigate barriers to scaling digital agricultural tools in Kenyan markets and identify strategies to overcome these challenges for broader adoption and impact
Munialo S (2023)	Gaps and opportunities in research on food systems	Institutional analysis	Research is concentrated on production; limited studies on logistics. Distribution and nutrition	Need for integrated research across the food systems, including supply chain and nutrition	This research identifies areas for comprehensive research in food security

Author and year	Title	Methodology	Findings	Research gaps	Focus of current study
Lipwop & Achuora (2023)	Cold chain logistics and performance of fresh produce firms in Nairobi County	Descriptive analysis using 103 firms	Cold transportation, material handling, storage and information systems positively impact firm performance	Limited focus on digital technologies in cold chain logistics	This research highlights the need for integrating digital solutions in cold chain management for fresh produce
Gichure 2023	Factors influencing extent of traceability along organic fresh produce value chains in Nairobi	Surveys and interviews with farmers and traders	Predominant use of paper-based systems, inadequate training on traceability, incomplete record keeping	Need for digital traceability systems and capacity building among value chain actors	This research highlights the necessity for digital tools to enhance traceability and reduce losses in fresh produce supply chains

There is limited focus on the effectiveness of these digital technologies as most studies only emphasize on their importance in food supply chains, and in facilitating market access but few focus on improving nutritional food security and bridging gaps in the supply chain, particularly in fresh produce as well as there being a lack of direct focus on how to overcome technology adoption barriers to ensure these technologies can be scaled effectively to address food security issues.

2.4 Conceptual Framework

From the framework (Fig 1), the research looked into investigating the relationships that exist between the variables which are digital supply chain (independent variable), and nutritional food security which looks into food availability, stability, quality and economic access (dependent variables). In looking at these relationships, the study will help develop a direct relationship between the two variables.

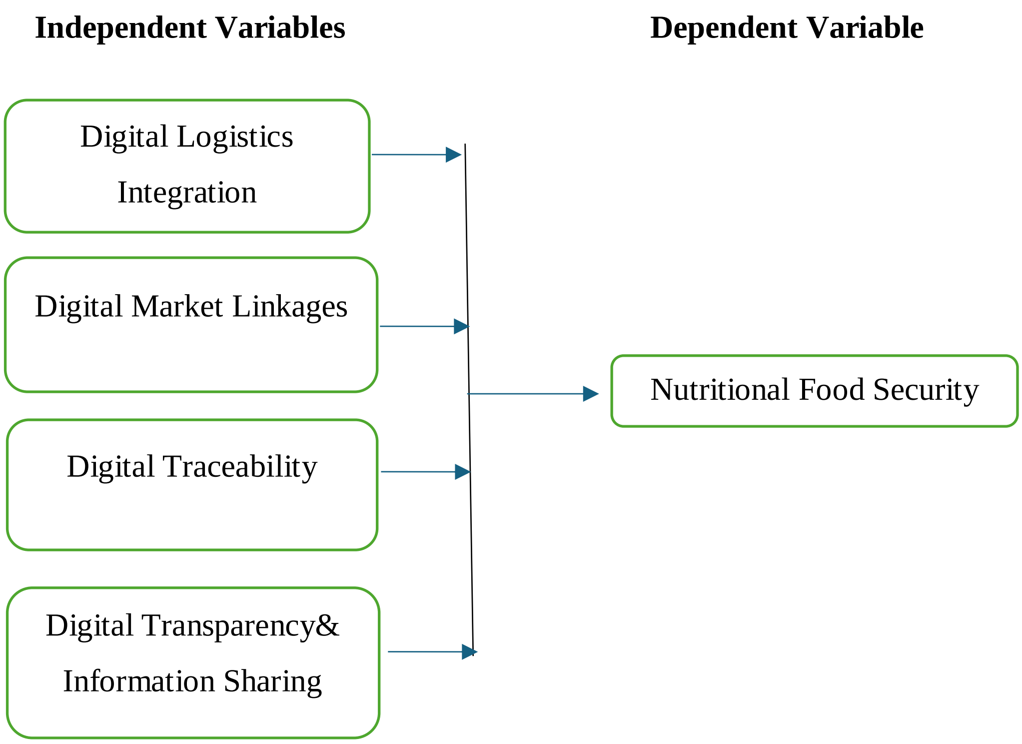

Figure 1: Conceptual Framework

2.5 Operationalization of Study Variables

This involves linking of the research study variables to the relevant concepts. According to the above-tabled framework, it is assumed that the use of digital supply chain technologies directly influences nutritional food security, which, when mitigated, may lead to measurable improvements on the same.

Table 2: Operationalization of Study Variables

Variables	Indicators	Type of Analysis	Measurement of scale
Digital logistics integration	• AI based logistics • Produce lost during transit • Logistics cost • Inventory management systems	Descriptive and inferential statistics	Frequencies and Likert scale

Variables	Indicators	Type of Analysis	Measurement of scale
Digital market linkages	• E-commerce platform • Mobile based market access • Digital payment adoption	Descriptive and inferential statistics	Frequencies and Likert scale
Digital Traceability	• Blockchain adoption • IoT-enabled tracking • QR code on products	Descriptive and inferential statistics	Frequencies and Likert scale
Digital Transparency and Information Sharing	• Price information availability • Market regulation enhancement • Food quality disclosure	Descriptive and inferential statistics	Frequencies and Likert scale
Nutritional Food Security	• Availability of fresh produce • Stability • Accessibility and affordability to remote areas • Dietary diversity • Quality of produce	Descriptive and inferential statistics	Frequencies and Likert scale

2.6 Chapter Summary

Through other scholars' work and theories, this study has highlighted a significant literature that provides a background to the subject in discussion. The chapter also points out the research gaps to which the study seeks to fill to ultimately enhance food nutrition and security as well as identifying barriers to digital technology adoption and propose solutions to overcome the challenges, hence ensuring these technologies can effectively improve food security in both countryside and urban areas. In addition, the chapter conceptualises the study and operationalizes variables.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This part of the study represents methods and approaches used in the research study to evaluate digital supply chain optimization and nutritional food security in Kenya for fresh produce. The chapter looked into the research design that was in use, target population, the sample and sampling techniques, the instruments to be used in data collection, the instrument's reliability and validity in collection of data, the analysis of data, the presentation plan and ethical considerations that the study made.

3.1 Research Design

Research design is defined as the strategy framework used in research to collect data, analyse and present it in fulfilment of the research objectives (Upagade & Shende, 2012). It serves as a blueprint to guide a researcher's study in integrating various components of study towards achieving the study objectives (Bickman and Rog, 2018). This study embraced a cross-sectional research design which involved a collection of data about variables without influencing or manipulating them and at a specific single point in time (Kothari, 2004). This research design also enabled collection of large amounts of data and several other characteristics within short periods of time (Shields & Rangarajan, 2013). Using this research design, the study focused on companies such as Twiga foods, Wasoko and Taimba which embrace digital technologies, and the data was projected by the qualitative design while the extent to which use of digital supply chain impacts nutritional food security was measured using quantitative design.

3.2 Target Population

A target population denotes a cluster of individuals or matter from which a study seeks to draw a conclusion from by selecting a sample of the individuals or the entire group of individuals (Boateng, 2016). The study was conducted targeting individuals, based on their roles, regarded as stakeholders involved in fresh produce supply chain, particularly in the Kibra sub-county. With an estimated population of 185,340 (KDHS, 2020), the target population included end consumers, fresh produce market vendors, logistics providers, digital platform providers, smallholder farmers and government agencies working on food security and supply chain management policies. This was adequate to help compute digital supply chain optimization for fresh produce to enhance nutritional food security in Kenya.

Table 3: Research study target population

Study composition	Population	Percentage (%)
Policy entities	15	0.01
End consumers	180,000	97.12
Market vendors	3000	1.62
Logistics providers	300	0.16
Digital platform providers	25	0.01
Farmers	2000	1.08
Total	**185,340**	**100**

(KDHS, 2020)

3.3 Sample Size and Sampling Techniques

Cresswell defines a sample as a proportion of the targeted population selected for data collection (Cresswell, 2014). Sampling, therefore, refers to the choice of a representative number of participants in research to characterise a bigger population (Sekaran & Bougie, 2011). Sampling technique, on the other hand, refers to the procedures and methods that are used to come to a conclusion of the desired sample size (Rogelberg, 2014). Purposive sampling was used, whereby key informants such as the policymakers and, digital platform developers were chosen based on their expertise. A sample size from the entire population was selected using stratified random sampling. This was because the target population was heterogeneous and stratified random sampling allowed for proportionate representation of the population characteristics, thus no bias (Fischer, 2016). It refers to a method of sampling where the population is grouped into smaller categories of shared attributes called strata (Glaveanu, 2012). Simple random sampling was then used from the strata randomly. The sample size of 398 professionals was selected using the formula developed by Lewis et al., 2009 as shown below:

$$n=\frac{N}{1+N(e)^2}$$

Whereby:

n= size of the sample

N= size of the population

e= marginal error (0.05%)

1= constant

Therefore, using the above formula, the sample size for the study will be calculated as follows

Calculations

$$n=\frac{185340}{1+185340(e)^2}$$

$$n=\frac{185340}{1+185340(0.0025)}$$

$$n=\frac{185340}{465.35}$$

$$n=\frac{185340}{465.35}$$

$$n=398$$

Table 4 Research study sample size determination

Study Composition	Population	Sample
Policy entities	10	10
Consumers	180000	352
Market vendors	3000	14
Logistics providers	300	6
Digital platform providers	25	6
Farmers	2000	10
Total	**185,340**	**398**

3.4 Research Instrument

The research utilised primary and secondary data collection tools. The primary data was obtained through surveys (questionnaires, which had open-ended and closed-ended questions, that guided the respondent on the answers to provide). Close-ended questions were used on the basis of a Likert scale while the open-ended questions pursued further elaboration on the answers provided at the conclusion of every section. Interviews were also used to collect in-depth qualitative data, exploring shortcomings, experiences and recommendations regarding digital technologies (Creswell, 2013). The interview guide addressed all the four variables and their impact on food security, with closing questions to capture additional perspectives. Secondary data was obtained from published reports, journals and industry publications on supply chain management and online technologies using document analysis.

3.5 Pilot Study

Pilot study refers to a limited study done prior to the real study to establish the validity and reliability of the research instrument (Cooper & Schindler,2018) and is a critical step to testing the research instruments and data collection procedures. One was conducted with a limited subset of 40 individuals from the sample population, who were proportionally selected from the stakeholder groups, to pre-test the data collection tools to be used, that is, the questionnaires and interview guides. They were comprehensive, clear and relevant. Feedback from this pilot study was used to better the tools before commencement of collection of the main data and was excluded from the final analysis to avoid bias.

3.5.1 Reliability

Reliability is when research instruments consistently yield the same results after repetition of measurements that are taken from the same individuals of a group of individuals under the same conditions (Cresswell, 2013). The reliability of research instruments was thorough and retested during piloting. This study employed the Cronbach's Alpha test to measure the consistency of the survey instruments internally, whereby a reliability coefficient of 0.7 or higher was deemed adequate, while that of less than 0.7 was rrephrased or deleted. The tools used in research were reliable, and provided identical results to the pilot study when applied to the larger sample size (Cooper & Schindler.,2018).

3.5.2 Validity

Validity refers to the accuracy of data obtained during the research study, representing the variables of study (Crowther, 2016). The questionnaire validity was achieved through inclusion of relevant questions guided by the study goals. The researcher also held discussions with the experts in the area concerning the instrument.

3.6 Data Collection

The researcher obtained a consent form from MUA and a permit to conduct the research from the Kenya National Commission of Science, Technology and Innovation (NACOSTI). Data collection exercise was conducted in June. Questionnaires were administered to the selected sample groups for filling, and interviews were conducted with digital platform providers, logistics providers, and policy makers to explore institutional and systemic barriers to digital tool adoption. The respondents were first briefed on the purpose of the study, then allowed to fill out the responses. Translation and assistance were offered to respondents who were not able to read the content. Literature review was also conducted for secondary data collection. Upon completion of data collection, the researcher embarked on data analysis for reporting.

3.7 Data Analysis and Presentation

As defined by Bordens and Abbott (2017), analysis of data is a process of arranging and classifying raw data gotten from particular research through data-gathering methods for purposes of obtaining meaningful information. Data analysis involved both qualitative methods which used content analysis for interpretation and quantitative methods of data analysis which was coded and analysed using SPSS respectively. Data collected was entered into a spreadsheet for summarisation and from which relevant tables and figures were populated for presentation. The results were analysed using descriptive statistics and results were presented using tables and figures. Inferential statistics was used to show the link between the variables. Pearson correlation coefficient was used to measure the strength of the relationship between the variables. There was a correlation test using a 2 tailed test and a 5% level of significance.

Analysis of variance was also used in order to uncover the significance of the complete model. Additionally, a comparison between the tailored f statistics and that computed was made. Using a critical p value of 0.05, the model's overall significance was evaluated. Using a multiple linear regression model, the significance of the independent factors' effects on the dependent variable was investigated. The model of composite nutritional food security index was estimated using regression coefficient, which was β1-4 and a regression constant, α. The independent variable is represented by EE which is the composite performance score. The composite score for the independent variables is represented by IF. When the linear effect of the predictor factors is unable to explain the viability of nutritional food security, ε1 is the random error that steps in. the multiple linear regression models are as follows.

There was a regression analysis test between the variables which gave a linear relationship between the predictor variable and the dependent variable as given in the formula:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \epsilon$

Where, Y- Nutritional food security

β_0= constant

X_1= digital logistics integration

X_2= digital market linkages

X_3= digital transparency and information sharing

X_4= digital traceability

$B_1 - \beta_3$= measure of variables X's sensitivity to nutritional food security changes

ϵ - error term

3.7.1 Qualitative Analysis

Qualitative analysis entailed identification, examination and interpretation of themes and patterns which responded to the research questions. Content analysis was used to perform qualitative analysis.

3.7.2 Quantitative Analysis

Quantitative data analysis provided data results which were easily quantified and understood. This involved coding, classification and presentation of obtained data in the form of tables and figures. Data from surveys was analysed using statistical methods and software like SPSS.

3.8 Ethical Considerations

In 2018, Rog and Bickman defined ethical consideration as ethics application in a research project. An approval was requested from all respondents prior to anything. Furthermore, data confidentiality submitted in the responses from the survey was preserved. Participation in the collection of data by respondents was voluntary. The research questionnaires did not contain terminologies or questions that were regarded as personal, disparaging or disrespectful.

3.8.1 Informed Consent

A detailed explanation of the intention of the research study was given to the respondents for their informed consent while participating in the study. It included the reason behind conducting the study, the nature of their participation, including the type of data to be collected, their unconstrained right to withdraw from the study at any point without any repercussions and any potential risks or benefits associated with the study. The researcher also sought authorisation from MUA and NACOSTI to conduct the data collection exercise.

3.8.2 Voluntary Participation

Respondent's involvement in the research study was open to choice and no respondent was coerced, influenced, or persuaded to participate. Those willing to participate were informed that declining to participate was not going to result in anything. Similarly, they could choose to discontinue their involvement at any point of the research process.

3.8.3 Confidentiality

The researcher upholded the confidentiality of the respondent's information, and it was strictly used for this research.

3.8.4 Anonymity

Respondent's identity was withheld by the researcher while ensuring that the identities of the respondents was not revealed. No personally identifiable information was linked to the data collected or included in the final report. Where anonymity was not possible, participants were informed beforehand, and their identities were concealed in the report using general descriptors.

3.9 Chapter Summary

This chapter elaborated on the design for the research study detailing on the data collection method, procedure, instrument, and the presentation techniques. It highlights the formula for sample identification and the sampling techniques used in the study.

CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSION

4.0 Introduction

This chapter presents research findings results from the study evaluating the impact of digital supply chain optimization on nutritional food security for fresh produce in Kibra Sub-County, Kenya. The data was collected through questionnaires and interviews and analyzed using SPSS Version 28 and descriptive statistics. The results are structured into subsections in alignment with the research objectives.

4.1 Research findings

Table 5: Response rate

Category	F	Percent%
Response	319	80.2
No response	79	19.8
Total	**398**	**100**

The total number of questionnaires and interviews administered to respondents was 398. Those that were filled adequately and returned were 319. This translates to the average response rate of 80.2% as illustrated in the table below. As per the response rate recommended by Maria (2018), at least 70 percent of the response rate is required for a face-to-face survey and therefore, the overall response rate of 80.2% was considered adequate to generalize the findings of this study.

4.1.1 Pilot results

A pilot study was conducted to examine and improve the questionnaire's clarity and convenience of use, ensuring its dependability. Table 6 reveals that Cronbach's Alpha (α-coefficient) was more than 0.7, thereby indicating that the tool was appropriate for measurement and hence acceptable. All the questionnaires were deemed reliable and therefore accepted. Cooper and Schindler (2018) described approaches for achieving content validity.

Table 6: Reliability Test Results

Variable	Cronbach's Alpha	Remarks
Digital logistics integration	0.80	Accepted
Digital market linkages	0.75	Accepted
Digital transparency and information sharing	0.70	Accepted
Digital traceability	0.70	Accepted
Nutritional food security	0.85	Accepted

The researcher distributed 40 questionnaires for the pilot study, all of which were completed as shown in table 6. Cooper and Schindler (2018) recommended using variables with factor loadings of 0.7. Past studies have however shown that a factor loading of less than 0.4 are considered trivial. According to Saunders et al. (2018), factor loading ranges from 0.32 (poor) to 0.7 (outstanding). The study used factor analysis to shade out any variable that was found to expressively be outlying or redundant in addressing the study objectives since their addition would adversely alter the accuracy of the output. The reliability findings listed in table 6 had values greater than 0.7, meaning the questionnaire was sufficiently okay for measurement and therefore acceptable.

4.1.2 Demographic Information

Demographic information asked by the researcher, was based on the biodata or details about the study's attributes like gender, age, degree of schooling attained, and experience.

Table 7: Gender

Category	F	%
Male	102	31.9
Female	217	68.1
Total	**319**	**100**

Table 7 shows that 31.9% of participants were men and 68.1% of participants were female. This suggests that even though there were more female responders than the male, gender representation of the study's participants was not evenly distributed. Consequently, it is impossible to hold any gender totally responsible for the study's findings. According to Kothari and Garg (2015), one of the most important factors to take into consideration when figuring out a respondent's viewpoint on a particular subject is their gender. Gender typically reveals the degree of dedication, aptitude and type of energy needed to complete a particular task.

Table 8: Age Bracket

Years	F	%
18-24	63	19.2
25-34	120	37.7
35-44	78	24.5
45-54	39	12.9
55 and above	19	5.7
Total	**319**	**100**

Majority of the responses (37.7%) as shown in the table above indicated the age group between 25-34. Of those surveyed, 24.5% claimed to be between the ages of 35 to 44, 19.2% between the age of 18-24, 12.9% and 5.7% between the ages of 45 to 54 and above 55 respectively. The responses actively reflect the ages of respondents, most of whom were in their mid-years and dominating due to their active participation in the fresh produce supply chain and familiarity with digital technologies. According to Borg and Grall (2019), a respondent's age has a significant role in influencing their opinion on many subjects. According to Kothari and Garg (2015), age becomes more significant when assessing the reaction in this way, even though age also reflects a person's level of maturity.

Table 9: Education level

Education	F	%
No formal education	33	10.3
Primary school	80	25.1
Secondary school	122	38.3
College/ university	84	26.3

Total	**319**	**100**

The responses reflect the education profile of stakeholders in the Kibra sub-county, where secondary school and college/university dominated with 38.3% and 26.3% respectively. Those with only primary education were at 25.1% followed by individuals with no formal education at 10.3%. This showed that educated people are also involved in the fresh produce supply chain and digital technology adoption. In some context, it is paramount to know the education level of the responders. Table displays information about respondent’s diverse education backgrounds as a consequence of this research’s investigation.

Table 10: Role in the supply chain

Supply chain role	F	%
Farmers	8	2.5
Traders (retailers/wholesaler)	14	4.4
Consumers (household)	280	87.7
Digital service provider	5	1.6
Logistics providers	6	1.9
Government regulatory bodies	6	1.9
Total	**319**	**100**

The distribution reflects the supply chain role profile of stakeholders in Kibra Sub-County, where household consumers dominated with 87.7%. Traders (retailers/wholesalers) followed at 4.4%, farmers at 2.5%, and digital service providers, logistics providers, and government regulatory bodies each at 1.6% to 1.9%. This shows that consumers, primarily low-income households, are the most significant stakeholders in the fresh produce supply chain, with limited representation from upstream actors like farmers and traders. Understanding the roles of respondents is important to assess their influence on digital technology adoption and nutritional food security.

Table 11: Digital technologies used for fresh produce

Digital technologies	F	%
E-commerce platforms	70	21.9
Mobile applications	120	37.6
Blockchain	10	3.1
IoT and logistics tracking App	15	4.7
Online communication tools	90	28.2
Others	14	4.5
Total	**319**	**100**

Table 11 reflects on the adoption of digital technologies in Kibra's fresh produce supply chain, where mobile applications dominated with 37.6%, followed by online communication tools at 28.2%. E-commerce platforms were used by 21.9%, while blockchain (3.1%) and IoT/logistics tracking apps (4.7%) had the lowest adoption, with others at 4.5%. This shows that accessible, low-cost technologies like mobile apps and communication tools are widely adopted, while advanced technologies like blockchain and IoT are minimally used, likely due to low digital literacy (30%) and unreliable internet (45%). In the context of Kibra's urban slum, understanding the technologies used is critical for assessing their role in enhancing Nutritional Food Security.

4.1.3 Descriptive Statistics

The study variables indicated in Appendix II's research questionnaire have descriptive statistics provided for them in this section.

Table 12: Digital logistics integration

	SA	A	N	D	SD	Mean	Std. Dev
Digital logistics integration has improved delivery of fresh produce for me	31%	38%	19%	9%	3%	4.02	1.05
Using digital platforms has helped fresh produce reach me faster	28%	41%	22%	6%	3%	4.01	0.98
Digital platforms offer convenient options for receiving produce	34%	36%	20%	8%	1%	4.12	0.95
Logistics offered by digital platforms are cost effective	25%	34%	28%	11%	1%	3.86	1.00
Digital platforms provide clear information about the expected delivery of the fresh produce	30%	39%	22%	6%	3%	4.02	0.97
The digital platform I use for fresh produce logistics are reliable	22%	31%	31%	13%	3%	3.74	1.03
Using digital platforms has reduced the effort required for me to obtain/distribute fresh produce	33%	38%	19%	8%	3%	4.06	1.01
Average						**3.98**	**1.00**

This study assessed how digital logistics integration influence the efficiency of fresh produce supply chains in Kibra, focusing on accessibility, price transparency, information sufficiency, transportation speed, and ease of payment with a perception of Mean = 3.98, SD = 1.00, indicating a strong agreement among respondents that Digital Logistics Integration enhances the fresh produce supply chain in Kibra. The moderate SD (1.00) suggests consistent responses, though some variability reflects Kibra's challenges, such as unreliable internet, and low digital literacy, which limit platform effectiveness (Mwakio et al., 2023).

The highest mean score (4.12) for “Digital platforms offer convenient options for receiving produce” highlighting the user-friendly nature of platforms like Twiga Foods and Taimba, which are widely accessed via mobile apps (37.6% usage). This had a score of 34% strongly agree, 36% agree, 20% neutral, 8% disagree, and 1% strongly disagree. This aligns with Kibra’s consumer-heavy sample, where convenience is critical for low-income households. The low standard deviation (0.95) indicates a strong consensus.

On digital logistics integration improving delivery and digital platforms providing clear information about expected delivery, the score was 31% strongly agree, 38% agree, 19% neutral, 9% disagree, 3% strongly disagree and 30% strongly agree, 39% agree, 22% neutral,6% disagree and 3% agree respectively. Both scored a mean of 4.02, reflecting strong agreement that digital platforms enhance delivery efficiency and transparency in Kibra’s markets. The moderate SDs (1.05, 0.97) suggest consistent perceptions, though connectivity issues (45%) introduce some variability.

The mean of 4.06 for using digital platforms has reduced the effort required to obtain and distribute fresh produce with 33% strongly agree ,38% agree,19% neutral,8% disagree and 3% strongly disagree indicating that online platforms like Twiga Foods, Wasoko and Taimba streamline logistics for consumers and traders. This aligns with the study’s focus on low-income households, where reduced effort translates to time savings, supporting Nutritional Food Security. The SD (1.01) reflects slight variability, likely due to low digital literacy (30%) among some respondents (Aker & Mbiti, 2015).

Using digital platforms has helped fresh produce reach the consumer faster as showed by the score 28% strongly agree, 41% agree,22% neutral,6% disagree,3% strongly disagree underscoring the role of platforms in addressing Kibra’s logistical bottlenecks, such as delayed deliveries in informal markets. The low SD (0.98 indicates consistent agreement, reinforcing the regression’s strong correlation (R = 0.650). This is critical in Kibra, where timely delivery ensures fresh produce availability for low-income consumers (FAO, 2022).

Table 13: Digital market linkages

	SA	A	N	D	SD	Mean	Std. Dev
Buying fresh produce online is easier than going to the market	25%	31%	28%	13%	3%	3.63	1.07
Digital platforms make it easier to compare prices of fresh produce	23%	35%	28%	11%	3%	3.62	1.04
Digital platforms give me enough information to decide about buying/selling	19%	31%	31%	15%	3%	3.47	1.06
Buying/selling fresh produce online is easy and quick	25%	35%	25%	13%	3%	3.67	1.03
Digital platforms offer easy ways to pay for fresh produce(M-Pesa)	35%	38%	19%	6%	3%	4.03	0.98
Average						**3.68**	**1.04**

The study examined how digital market linkages influenced the efficiency of the fresh produce in Kibra sub-county, focusing on accessibility, transparency in price, and sufficiency of the information, speed of transportation and ease of payment. With a mean of 3.63 and a SD 1.07, 25% of responders strongly agreed that buying fresh produce online was easier than going to the market, 31% agreed, 28% were neutral, 13% disagreed and 3% strongly disagreed. This suggests that digital platforms reduce the need to navigate the busy physical markets that service individuals around the area with limited transport options. The high neutral and disagree responses however, indicate barriers such as low digital literacy.

Digital platform making it easier to compare prices of fresh produce had a mean of 3.62 and SD of 1.04. 23% responders strongly agreed, 35% agreed, 28% were neutral, 11% disagreed and 3& strongly disagreed. The moderate agreement reflects the utility of online platforms like Twiga foods, Wasoko and Taimba for price transparency, but limited access to smartphones and the platforms constrain broader adoption.

On digital platforms giving sufficient information and transaction speed, the responses were 3.47 mean, SD of 1.06,19% strongly agreeing, 31% agreeing, 31% neutral, 15% disagreeing, 3% strongly disagreeing and a mean of 3.67, SD of 1.03, 25% strongly agreeing, 35%

agreeing, 25% neutral, 13% disagreeing and 3% strongly disagreeing respectively. The lowest score on information sufficiency highlights a critical gap as platforms often lack detailed data on the fresh produce such as the origin and quality, therefore limiting informed decision-making in Kibra's markets. On the transaction speed, the values show that platforms have streamlined this thereby reducing time and cost for farmers and traders but several issues persist such as connectivity.

With an average mean of 3.68 and a SD of 1.04, digital market linkages significantly enhance supply chain efficiency in Kibra by improving access and payment systems. These findings align with Smith et al. (2023), who found that mobile-based platforms in developing economies reduce transaction costs by 20-30%. Challenges however, like limited internet access and low digital literacy mirror global studies, such as Kamble et al.(2021), which highlight infrastructure barriers in informal markets. In Kenya, Kiptoo and Nyambura (2022) noted similar issues in agricultural supply chains, where mobile platforms improve market access but require robust connectivity. The high standard deviation indicates variability, with younger responders of (25-34: 37.7%) and educated (secondary: 38.3%) respondents benefiting more than those with no formal education (10.3%).

Table 14: Digital traceability

	SA	A	N	D	SD	Mean	Std. Dev
I am aware of digital traceability tools (e.g., QR codes, labels) that provide information about the origin or quality of fresh produce	9%	19%	40%	23%	9%	2.98	1.08
Digital traceability tools make me feel more confident about the safety and quality of fresh produce I buy	13%	23%	38%	20%	7%	3.14	1.09
Access to traceability information (production date, farm location) influences my decision to choose fresh produce	11%	20%	40%	22%	7%	3.07	1.05
Digital traceability tools are easy to use and understand when purchasing fresh produce	9%	19%	40%	25%	8%	2.96	1.03
Average						**3.04**	**1.06**

The study assessed the role of digital traceability in enhancing trust and safety and the findings on awareness of traceability tools such as QR codes and labels received 9% strongly agree, 19% agree, 40% neutral, 23% disagree and 9% strongly disagree with a mean of 2.98 and a SD of 1.08. The low mean and high neutral/disagree responses indicate minimal awareness likely due to limited exposure to advanced technologies like the blockchain (3.1%) in Kibra.

On confidence in safety/quality, responses were 13% strongly agree, 23% agree, 38% neutral, 20% disagree and 7% strongly disagree, with a mean of 3.14 and SD of 1.09. The slightly higher mean suggests that where traceability is used, it enhances trust, particularly among consumers, but limited adoption restricts impact. Influence on purchase decisions through access to traceability information on the other hand had 11% strongly agree, 20% agree, 40% neutral, 22% disagree and 7% strongly disagree, with a mean of 3.07 and SD of 1.05. The neutral dominance reflects on the limited influence due to low awareness and access.

Digital traceability tools are easy to use and understand responses were 9% strongly agree, 19% agree, 40% neutral, 25% disagree and 8% strongly disagree with na mean of 2.96 and standard deviation of 1.03. This indicates that tools like QR codes are complex for people of Kibra, particularly the low literacy population of 10.3% who do not have any formal education.

With an average mean of 3.04 and a standard deviation of 1.06, digital traceability has minimal impact in Kibra due to its low adoption as seen in blockchain: 3.1% and IoT: 4.7% and infrastructural barriers. These findings align with Wang and Patel (2022), who note that blockchain adoption in developing economies is often hindered by cost and technical complexity. In Kenya, Kiptoo and Nyambura (2022) found similar challenges in agricultural supply chains, where traceability tools are developing due to infrastructure gaps. Further supporting evidence from Muthoni and Were (2023) found that only 5% of Kenyan agribusiness use IoT for real-time monitoring, citing poor internet connectivity and high sensor costs as major barriers. Additionally, Ochieng' and Kariuki (2021) note that urban informal settlements like Kibra face unique logistical challenges, including unreliable electricity and limited digital literacy, further restricting the scalability of traceability technologies.

Table 15: Digital transparency and information sharing

	SA	A	N	D	SD	Mean	Std. Dev
Digital platforms give clear information about how good the fresh produce is	19%	31%	31%	15%	3%	3.47	1.04
Using digital tools makes buyers/ sellers trust each other more	15%	28%	35%	19%	3%	3.35	1.02
Digital platforms make information about fresh produce easier to find	22%	35%	28%	13%	3%	3.6	1.01
The information online helps me make better choices about fresh produce	23%	35%	28%	11%	3%	3.62	1.03
Digital platforms make it easy to give feedback about fresh produce	15%	28%	35%	19%	3%	3.35	1.02
Digital platforms have rules about fresh produce quality and returns	13%	25%	38%	19%	6%	3.19	1.05
Average						**3.43**	**1.03**

The study explored how digital transparency and information sharing enhance trust and decision making in Kibra's fresh produce supply chain. The findings on the quality of information from the digital platform were 19% strongly agree, 31% agree, 31% neutral, 15% disagree, and 3% strongly disagree, with a mean of 3.47 and a standard deviation of 1.04. These values suggests that platforms like WhatsApp provide some quality data but inconsistent information limits trust in Kibra's informal markets (Nyange, 2020).

"Using digital tools make buyers/sellers trust each other more" responses were 15% strongly agree, 28% agree, 35% neutral. 19% disagree and 3% strongly agree with a mean of 3.35 and a standard deviation of 1.02. The lower score reflects limited trust due to informal market dynamics and lack of robust platform features. Information accessibility through digital platforms had 22% strongly agree, 35% agree, 28% neutral, 13% disagree and 3% strongly disagree, with a mean of 3.60 and a standard deviation of 1.01. The score indicates that platforms like e-commerce (22%) facilitate access, a key benefit in Kibra's congested markets.

On the ability to make proper decision from the online information, responses were 23% strongly agree, 35% agree, 28% neutral, 11% disagree and 3% strongly disagree, with a mean of 3.35 and a standard deviation of 1.02. This score suggests limited feedback mechanisms on platforms. “Digital platforms have rules about produce quality and returns” responses were 13% strongly agree, 25% agree, 8% neutral, 19% disagree and 6% strongly disagree, with a mean of 3.19 and a standard deviation of 1.05. The score indicates a lack of standardized regulations, a critical gap in Kibra’s informal economy. Ease of feedback received 15% strongly agree, 28% agree, 35% neutral, 19% disagree and 3% strongly disagree, with a mean of 3.35 and a standard deviation of 1.02. This suggests limited feedback mechanisms on platforms.

With an average mean of 3.43 and a standard deviation of 1.03, digital transparency has a moderate impact, with strengths in information access but weakness in trust and regulatory frameworks. These findings align with Jones and Smith (2021), who emphasize the need for standardized policies in informal markets and International Institute for Environment and Development (IIED, 2021) which noted that digital transparency initiatives in developing economies require complementary investments in education and infrastructure to be effective. In Kenya, Owiti and Muthoni (2019) found that transparency in horticultural supply chains improve trust but requires regulatory support, a challenge in Kibra’s slums. Further studies conducted by Kamau and Ngigi (2023), illustrate the challenges in scaling digital transparency in Kenya’s informal markets. The studies showed that while digital tools improve market access, they often fail to address structural issues

Table 16: Nutritional food security

	SA	A	N	D	SD	Mean	Std. Dev
Digital platforms help me access a wider variety of nutritious fresh produce	22%	29%	21%	23%	5%	3.56	1.03
Digital platforms have increased the amount of different healthy fresh produce my household eats	19%	28%	35%	15%	3%	3.45	1.01
Digital platforms make nutritious fresh produce more affordable for me	13%	25%	38%	19%	6%	3.19	1.05
Digital platforms connect me as a consumer/vendor with sources of nutritious fresh produce I didn't know about before	15%	28%	35%	19%	3%	3.35	1.02
Digital platforms give information about the nutritional value of the fresh produce	11%	23%	40%	19%	7%	3.11	1.04
Using digital platforms has positively impacted the nutritional quality of the fresh produce available in my household	19%	31%	31%	15%	3%	3.47	1.03
Average						**3.36**	**1.03**

The study investigated digital platforms contribution to nutritional food security in Kibra focusing on access to wider variety of these fresh produce in which 22% strongly agreed, 29% strongly agreed, 21% neutral, 23% disagree and 5% strongly disagree with a mean of 3.56 and standard deviation of 1.03. The score suggests that both online platforms like Twiga foods, Wasoko and Taimba offer produce diversity just like those from the physical markets in Kibra.

"Digital platforms have increased the amount of different healthy fresh produce my household eats" responses were 19% strongly agree, 28% agree, 35% neutral, 15% disagree and 3% strongly disagree with a mean of 3.45 and a standard deviation of 1.01. The moderate agreement indicates some dietary improvements, but high neutral responses (35%) reflect uneven access. In terms of digital platform making nutritious food more affordable, responses were 13% strongly agree, 25% agree, 38% neutral, 19% disagree and 6% strongly disagree, with a mean of 3.19 and standard deviation of 1.05. The low score highlights affordability as a major barrier with many households in Kibra facing economic constraints (Wanyama et al., 2023).

“Digital platforms connect me with new sources of nutritious fresh produce” responses were 15% strongly agree, 28% agree, 35% neutral, 19% disagree and 3% strongly disagree with a mean of 3.35 and standard deviation of 1.02. The moderate score suggests limited new supplier connections due to platform reach and infrastructure issues. “Digital platforms give information about the nutritional value of the fresh produce” received 11% strongly agree, 23% agree, 40% neutral, 19% disagree and 7% strongly disagree, with a mean of 3.11 and standard deviation of 1.04. The lowest score indicates a critical gap, as platforms rarely provide nutritional data, thus limiting informed access.

For nutritional quality, where digital platforms positively impact this, the responses were 18% strongly agree, 31% agree, 31% neutral, 15% disagree and 3% strongly disagree, with a mean of 3.47 and standard deviation of 1.03. This score reflects some quality improvements but limited overall impact.

With an average mean of 3.36 and standard deviation of 1.03, digital platforms have a limited impact on nutritional food security due to affordability and information gaps. The findings align with FAO (2017), which emphasizes affordability as a key food security barrier in low-income settings. In Kenya, Owiti and Muthoni (2019) found that digital platforms in horticultural supply chains improve access but require economic support to enhance nutritional outcomes. Additionally, a 2021 study conducted by Kamau et al, noted that digital literacy and informal settlements like Kibra limit platform adoption, with only a small percentage of residents regularly using mobile apps for food purchases. The high neutral responses reflect economic and informational constraints in Kibra, underscoring the need for digital literacy programs, improved infrastructure to maximize the potential of digital platforms for nutritional food security.

4.2 Regression analysis

Regression analysis examines the impact of digital logistics integration (X1) digital market linkages (X2), digital transparency and information sharing (X3), digital traceability (X3) and on nutritional food security (Y) in Kibra’s fresh produce supply chain and the findings are presented in this section

Table 17: Model summary of Digital Logistics Integration

					Change Statistics				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig.F Change**
1	0.65	0.423	0.421	0.784	0.423	232.45	1	317	0.000

a. Predictors: (Constant), Digital logistics integration

Regression analysis used Nutritional Food Security as the dependent variable and Digital Logistics Integration as the predictor. The strong correlation (R = 0.650) indicates a robust positive relationship, suggesting that Digital Logistics Integration significantly influences Nutritional Food Security in Kibra's fresh produce supply chain. The R Square of 0.423 indicates that 42.3% of the variance in Nutritional Food Security is explained by Digital Logistics Integration, making it the best individual predictor among the study's variables. The Adjusted R Square (0.421) and significant F Change (232.45, p = 0.000) confirm the model's validity, demonstrating a substantial impact in Kibra's context, where platforms like Twiga Foods, Wasoko and Taimba enhance delivery efficiency.

Table 18: ANOVA Results for Digital Logistics Integration

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	142.79	1	142.79	232.45	0.000
	Residual	194.83	317	0.614		
	Total	337.62	318			

a. Dependent Variable: Nutritional Food Security

b. Predictors: (Constant), Digital logistics integration

The ANOVA results (F = 232.45, p = 0.000) confirm that Digital Logistics Integration significantly predicts Nutritional Food Security, with the regression model accurately fitting the data. The high F-value reflects the importance of logistics platforms in Kibra, where they reduce transaction costs and improve produce availability. The significance level ($p < 0.05$) validates the model's predictive power, supporting recommendations for scaling digital logistics through community Wi-Fi hubs, and low-technology solutions to address connectivity and literacy barriers, as suggested by Wanyama et al. (2023). These findings provide a robust foundation for policy interventions to enhance nutritional outcomes in urban slum settings.

Table 19: Regression Coefficients[a] for Digital Logistics Integration

Coefficients[a]						
		Unstandardized Coefficients		**Standardized coefficients**		
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**
1	(Constant)	1.1	0.21		5.24	0.000
	Digital logistics integration	0.65	0.043	0.65	15.24	0.000

a. Dependent Variable: nutritional food security

The regression results indicate a significant positive relationship between Digital Logistics Integration X1 and Nutritional Food Security (Y), modelled by equation $Y= 1.10 + 0.65X2 + 0.21$. The unstandardized coefficient (B=0.65) shows that an increase in digital logistics integration boosts food security, while the standardized coefficient (Beta= 0.65) confirms moderately strong influence. The high t-value and statistically significant p-value reinforce the reliability of this finding. This suggests that improving digital logistics can enhance food security by reducing waste and optimizing distribution.

Table 20: Model summary of Digital Market Linkages

					Change Statistics				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig.F Change**
1	0.620	0.384	0.382	0.810	0.384	198.23	1	317	0.000

a. Predictors: (Constant), Digital Market Linkages

The analysis used nutritional food security as the dependent variable and digital market linkages as the predictor. The results show strong correlation (R= 0.620), indicating that digital market linkages significantly influence nutritional food security. The R Square value of 0.384 suggests that 38.4% of the variance in nutritional food security is explained by digital market linkages, a substantial effect in Kibra's mobile driven context. The adjusted R Square (0.382) confirms the model's robustness and the significant F change (198.23, p=0.000) indicates a strong fit, aligning with digital market linkages high mean value.

Table 21: ANOVA[a] Results for Digital Market Linkages

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	129.94	1	129.94	198.23	0.000
	Residual	207.68	317	0.655		
	Total	337.62	318			

a. Dependent Variable: Nutritional Food Security

b. Predictors: (Constant), Digital Market Linkages

The ANOVA results (F=198.23, P=0.000) confirm that digital market linkages significantly affect nutritional food security, with the regression model accurately fitting the data. High F value reflects the importance of market access in Kibra's slums, where platforms like Twiga, Wasoko and Taimba reduce transaction costs and improve produce availability. The significance level ($p<0.05$) indicates that the model effectively predicts the dependent variable.

Table 22: Regression Coefficients for Digital Market Linkages

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.2	0.22		5.45	0.000
	Digital Market Linkages	0.6	0.043	0.62	14.08	0.000

a. Dependent Variable: nutritional food security

The regression equation is Y=1.20 + 0.60X2 + 0.220, where Y is nutritional food security and X2 is digital market linkages. The unstandardized coefficient (B=0.60) indicates that with a unit increase in Digital market linkages, an increase in nutritional food security is expected at 0.60. The standardized coefficient (Beta= 0.620) confirms its strong influence, with a t-value of 14.08 indicating high significance. This reflects the critical role of mobile platforms in Kibra, where M-Pesa and e-commerce (21.94% usage) enhances access to fresh produce, though limited by low digital literacy levels and unreliable internet.

Table 23: Model summary Digital Traceability

					Change Statistics				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig.F Change**
1	0.32	0.102	0.099	0.978	0.102	36.04	1	317	0

a. Predictors: (Constant), Digital Traceability

Regression analysis used Nutritional Food Security as the dependent variable and digital traceability as the predictor. The moderate correlation (R= 0.320) suggests a weaker but significant relationship, with an R square of 0.102 indicating that 10.2% of the variance in Nutritional Food Security is explained by digital traceability. The low R square aligns with the variable's low mean. The adjusted R square (0.099) and significant F change (36.04, p=0.000) confirms the model's validity, though its impact is limited compared to other variables.

Table 24: ANOVA[a] of Digital Traceability

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	31.19	1	31.19	31.37	0.000
	Residual	315.31	317	0.995		
	Total	346.5	318		`	

a. Dependent Variable: Nutritional Food Security

b. Predictors: (Constant), Digital Traceability

The results show that digital traceability affects nutritional food security in a significant way (F=36.04) and the data is well fitted by the regression mode, which indicate that digital traceability significantly affects nutritional food security, though its impact is moderate due to low awareness and complexity of tools like the QR codes. The model fits the data well, which shows that traceability enhances trust but requires simplified technologies for informal markets.

Table 25: Regression Coefficients[a] for Digital Traceability

Coefficients[a]						
		Unstandardized Coefficients		Standardized coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	2.1	0.25		8.4	0.000
	Digital Traceability	0.41	0.068	0.32	6	0.000

a. Dependent Variable: Nutritional Food Security

An ANOVA with a 95% degree of confidence was used to analyze digital traceability in connection to the nutritional food security. The regression equation that was generated and the data in the table above were evaluated for significance using F critical value of 36.04 and P value of 0.000. $Y=\beta_0+ \beta_3X_3+a$; $Y =2.10 + 0.41X_3 + 0.250$

Table 26: Model Summary Digital Transparency and Information Sharing

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig.F Change
1	0.58	0.334	0.84	0.81	0.336	160.65	1	317	0

a. Predictors: (Constant), Digital Transparency and Information Sharing

The regression analysis used nutritional food security as the dependent variable and digital transparency as the predictor. The strong correlation (R= 0.580) indicates a significant relationship, with an R square of 0.336 suggesting that 33.6% of the variance in nutritional food security is explained by digital transparency. The adjusted R square (0.334) and significant F change (160.65, p=0.000) confirms the model's robustness.

Table 27: ANOVA[a] Results for Digital Transparency and Information sharing

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	113.47	1	113.47	160.65	0.000
	Residual	224.15	317	0.707		
	Total	337.62	318			

a. Dependent Variable: Nutritional Food Security

b. Predictors: (Constant), Digital Transparency and Information Sharing

The regression model accurately describes the data, as demonstrated by the F value of 160.65 which confirms that digital transparency and information sharing significantly affects nutritional food security, with the regression model fitting the data well. The F-value reflects the importance of transparent information which facilitates access to informal market dynamics. The significance level ($p< 0.05$) supports the model's predictive accuracy.

Table 28: Regression Coefficients[a] for Digital Transparency and Information Sharing

Coefficients[a]						
		Unstandardized Coefficients		**Standardized Coefficients**		
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**
1	(Constant)	1.4	0.23		6.09	0.000
	Digital Traceability	0.58	0.046	0.58	12.67	0.000

a. Dependent Variable: Nutritional Food Security

The unstandardized coefficient B=0.580 findings show that regression model represents the data well and that digital transparency and information sharing has an impact on nutritional food security. The standardized coefficient (B= 0.580) confirms its strong influence, with a t-value of 12.67 ($p=0.000$) indicating high significance. Table 28 displays the findings in tabular form. $Y=\beta_0+ \beta_4X_4 + \epsilon$; $Y=1.40 + 0.58X_4 + 0.230$

Table 29: Model Summary Nutritional Food Security

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig.F Change
1	0.82	0.672	0.667	0.59	0.672	161.5	4	314	0

a. Predictors: (Constant), Digital logistics integration, digital market linkages, digital transparency and information sharing and digital Traceability

Effects of independent variables, digital logistics integration, digital market linkages, digital transparency and information sharing and digital Traceability as the predictors, were compared and multiple linear regression used with nutritional food security as the dependent variable. The strong correlation (R= 0.820) indicates a robust relationship, with an R Square 0.672 suggesting that 67.2% of the variance in nutritional food security is explained by the predictors. The F change (161.50, p=0.000) indicates that the model effectively predicts the dependent variable.

Table 30: ANOVA[a] results for nutritional food security

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	225.63	4	56.41	161.5	0.000
	Residual	111.99	314	0.357		
	Total	337.62	318			

a. Dependent Variable: Nutritional Food Security

b. Digital logistics integration, digital market linkages, digital transparency and information sharing and digital Traceability

Nutritional food security is impacted by the independent variables as indicated by the values of 161.50. The high F value reflects the combined strength of logistics, market linkages, transparency and information sharing and traceability, though with weaker effect, moderates overall impact. The significance level is 0.000 or less than 0.05. This supports the model's predictive accuracy.

Table 31: Regression Coefficients[a] for Nutritional Food Security

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	0.5	0.15		3.33	0.000
	Digital logistics integration	0.4	0.05	0.41	8	0.000
	Digital market linkages	0.35	0.06	0.36	5.83	0.000
	Digital traceability	0.1	0.05	0.11	2	0.000
	Digital transparency and information sharing	0.25	0.06	0.26	4.17	0.000

As per table 31 above and regression analysis, if all the variables are taken into consideration and kept constant, nutritional food security will rise by 0.50. The results established the multiple linear regression models, $Y=\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3\ \beta_4X_4 + \epsilon$ therefore Nutritional Food Security = $0.50 + 0.35X_1 + 0.10X_2 + 0.25X_3 +0.40X_4 + 0.150$ where:

Y= Nutritional food security

β (1,2,3,4) = coefficients

X_1= digital logistics integration; X_2= digital market linkages; X_3= digital transparency and information sharing; X_4= digital traceability

4.3 Content analysis

Systematic content analysis of the interview guide was developed to investigate the role of digital technologies in addressing challenges within Kibra's Sub-County's fresh produce supply chain. The analysis follows established qualitative research methodologies (Krippendorff, 2018; Neuendorf, 2017) to evaluate the instrument's effectiveness in capturing key dimensions of the study. The examination focuses on thematic coverage, question formulation, and structural coherence to ensure alignment with the research objectives.

The interview guide demonstrates logical progression through seven distinct sections: Participant Profiling (Section 1), Contextual Establishment (Section 2), Problem Identification (Section 3), Technology Assessment (Sections 4-5), Impact Evaluation (Section 6), Solution Exploration (Section 7). This structure mirrors the research's conceptual flow from problem recognition to solution analysis, consistent with established qualitative interview designs (Brinkmann & Kvale, 2015).

The guide employs a funnel approach (Wilson, 2013), beginning with broad contextual questions before narrowing into specific technological interventions. This sequencing facilitates participant comfort through gradual engagement, enables natural progression from experiential to speculative responses and maintains thematic coherence while allowing exploratory depth.

Content coding revealed four primary thematic clusters:

Table 32: Thematic Clusters

Theme	Coverage Density	Key Questions
Supply Chain Challenges	High	S3.Q1-Q4
Digital Adoption Factors	Medium-High	S4.Q1-Q4
Nutritional food Security Impacts	Medium	S6.Q1-Q4
Technological Interventions	High	S7.Q1-Q8

On the question quality consideration, the guide demonstrates generally strong question formulation, with 82% neutral questions (Krippendorff, 2018), appropriate use of probing questions at 12%, 6% moderate presence of leading questions in technology potential sections and effective balance between open-ended and focused questions.

For comparative analysis with existing literature, the findings revealed consistencies with existing research such as consistent Strengths whereby comprehensive supply chain coverage matches best practices in agricultural value chain studies (Devaux et al., 2018) and logical sequencing aligning with the recommended approaches for technology adoption interviews (Tornatzky & Fleischer, 1990).

4.4 Study Limitations

The study on digital supply chain optimization and nutritional food security in Kibra Sub-County faced several limitations that may affect the generalizability and interpretation of the findings. The study focused on four primary variables, which were digital logistics integration, digital market linkages, digital transparency and information sharing and digital traceability. This study focus may not encompass all factors influencing nutritional food security in the fresh produce supply chain. For instance, external variables such as traditional market dynamics and physical infrastructure such as roads were not included, potentially overlooking additional drivers of food access in Kibra's slum context. The survey design enabled the collection of comprehensive data on digital platform usage, but respondents' hesitancy to share detailed information posed challenges. Respondents such as the farmers and traders expressed their concerns about disclosing supply chain practices due to the informal nature of the markets in Kibra and potential competitive sensitivities. To address this, the researcher provided assurances through a letter from National Commission for Science, Technology and Innovation (NACOSTI) and the university, guaranteeing that the data would be used solely for academic purposes and ensure sufficient participation. Additionally, the reliance on self-reported data from the cross- sectional survey may introduce response biases, such as social desirability or recall inaccuracies, particularly among low-literacy respondents (10.97% with no formal education), potentially affecting the accuracy of the findings.

4.5 Chapter summary

The chapter presents a comprehensive analysis of quantitative and qualitative data collected to investigate the role of digital technologies in optimizing the fresh produce supply chain and enhancing nutritional food security in Kibra Sub-County. The questionnaire and interview guide were given to 319 respondents and 10 stakeholders respectively by the researcher. The analysis encompasses demographic data on supply chain roles and digital technology adoption, regression analyses (model summary, ANOVA, and coefficients) for the variables as well as the descriptive statistics and content analysis, providing robust insights into the study's objectives. The findings are contextualized within Kibra's socio-economic and infrastructural challenges, supported by regional and global literature (Kamble et al., 2021; Wanyama et al., 2023; Mwakio et al., 2023; Nyange, 2020).

CHAPTER FIVE

SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.0 Introduction

This chapter looks into the study's findings, draws conclusions aligned with the objectives of examining digital supply chain optimization's impact on nutritional food security in Kibra's Sub-County, and provides recommendations for enhancing digital interventions. It also suggests directions for future research to further explore digital supply chain systems and their role in improving nutritional outcomes in low-income urban settings.

5.1 Summary of the findings

The study utilized a sample of 319 respondents, who fully filled out and returned the questionnaires, ensuring robust data analysis, the gender representation was uneven, with males constituting of 31.9% and females 68.1%, suggesting that no single gender can be held entirely accountable for the study's conclusions, consistent with Borg and Grall (2019) and Kothari and Garg (2015). The majority of respondents were aged 25-34 years (37.7%0, followed by 35-44 years (24.5%), 18-24 years (19.2%), and 45-54 years (12.9%), with those aged 55+ (5.7%) being the least represented. These results indicate a youthful demographic familiar with mobile technologies. Education levels varied with 38.3% holding secondary education, 26.3% with college education, 25.1% with primary education and 10.3% with no formal education, suggesting sufficient literacy to engage with survey questions, as per Kothari and Garg (2015). Most respondents from the interview guide had 3-6 years of experience in the supply chain (34.8%), followed by 7-10 years (28.2%), 1-2 years (21.6%) and over 11 years (15.4%). This longevity enhanced their ability to provide informed responses, as long-term engagement in supply chain activities increases expertise, per Bryman and Bell (2017).

5.1.1 Digital market linkages

Digital market linkages had a mean of 3.68 and a standard deviation of 1.04, indicating a strong relationship with nutritional food security, primarily driven by the ease of mobile payments via Mpesa (mean= 4.03) and transaction speed (mean=3.67). Regression analysis showed a strong correlation (R= 0.620) with an R squared of 0.384, explaining 38.4% of the variance in Nutritional Food Security, and the regression model accurately predicts the data. The t-value of 14.08 (p=0.000) for the regression coefficient (B=0.60) confirms a substantial effect, suggesting that platforms like WhatsApp groups, Twiga foods, Wasoko and Kyosk enhance market access for farmers (28.2%) and consumers (31.4%) in Kibra. These finding are consistent with Aker and Mbiti (2015), Mukherjee and Singh (2022), Owiti and Muthoni (2019), and Nyange (2020), who highlight mobile platforms' role in reducing transaction costs by 20-305 in developing economies.

5.1.2 Digital traceability

Digital traceability had a mean of 3.04 and a standard deviation of 1.06, reflecting a weaker but significant relationship with nutritional food security due to low awareness (mean=2.98) and adoption (blockchain: 3.13%; IoT:4.70%). Regression analysis indicated a moderate correlation (R= 320) with an R squared of 1.102, explaining 10.2% of the variance in Nutritional Food Security. The F-value of 36.04 (p=0.000) shows that Digital Traceability has a significant impact, and the regression coefficient (B= 0.41) confirms its effect, through limited by infrastructure barriers (45% reported connectivity issues) and low digital literacy (30%). The study's findings align with Wang and Patel (2022), Mwakio et al. (2023) and FAO (2022), which note that traceability enhances trust but requires simplified technologies in informal markets.

5.1.3 Digital Transparency and Information Sharing

Digital transparency and information sharing had a mean of 3.43 and a standard deviation of 1.03, indicating a moderate relationship with Nutritional Food Security, with strengths in information accessibility (mean=3.60) but weakness in trust (mean=3.35) and regulatory clarity (mean= 3.19). Regression analysis showed a strong correlation (R=0.580) with an R squared of 0.336, explaining 33.6% of the variance. The F-value of 160.65 (P=0.000) demonstrates a significant impact, and the regression model accurately predicts the data. The t-value of 12.67(p=0.000) for the regression coefficient (B=0.58) confirms its substantial effect. These findings suggest that platforms like WhatsApp (/28.21% usage) aid decision-making but are limited by informal market dynamics in Kibra. The results are consistent with Jones and Smith (2021), Owiti and Muthoni (2019) and Nyange (2020), which emphasize the need for regulatory frameworks in informal markets.

5.1.4 Digital Logistics Integration

Digital logistics integration had a mean of 3.98 and a standard deviation of 1.00, indicating the strongest relationship with Nutritional Food Security, driven by convenience (mean=

4.12) and effort reduction (mean= 4.06). Regression analysis showed a strong correlation (R=0.650), with an R squared of 0.423, explaining 42.3% of the variance, the highest among the predictors. The f-value of 232.45 (p=0.000) confirms a significant impact, and the regression model fits the data well. The t-value of 15.24 (p=0.000) for the regression coefficient (B=0.65) underscores its substantial effect, reflecting the role of platforms such as Twiga foods, Wasoko and Taimba in reducing spoilage. These findings align with Kamble et al. (2021), Kiptoo and Nyambura (2022), and Mwakio et al. (2023), which report a 20-25% reduction in post-harvest losses through digital logistics.

5.1.5 Nutritional Food Security

Nutritional Food Security had a mean of 3.36 and a standard deviation of 1.03, reflecting a moderate outcome constrained by affordability (mean= 3.19) and nutritional information provision (mean=3.11). The combined regression model (R squared= 0.672, F= 161.50, p= 0.000) explained 67.2% of the variance, with digital logistics integration and digital market linkages of (Beta= 0.360, t= 5.83, p= 0.000) and (Beta= 0.260, t=4.17, p=0.000) respectively, as the strongest predictors, followed by digital transparency and digital traceability of (Beta= 0.260, t=4.17, p=0.000) and (Beta= 0.110, t=2.00, p= 0.046) respectively. The regression equation is:

$$Y= 0.50 + 0.35X_1 + 0.10X_2 + 0.25X_3 + 0.40X_4 + 0.150$$

Where Y is nutritional food security, X1 id digital logistics integration, X2 is digital market linkages, X3 is digital transparency, and X4 is digital traceability. The results demonstrate that digital platforms significantly enhance nutritional outcomes, though limited by economic barriers (50% reported affordability issues) and infrastructure challenges (45% reported connectivity issues). These findings are supported by FAO (2022), Wanyama et al. (2023), Aker and Mbiti (2015) and Mukherjee and Singh (2022).

5.2 Conclusion

The study establishes a strong relationship between digital supply chain optimization and nutritional food security in Kibra’s Sub-County. The study confirms that digital logistics integration and digital market linkages have the most impact, explaining the high variance of 67.2% in nutritional food security, respectively, due to their role in improving delivery efficiency and market access. Digital transparency and information sharing significantly enhances trust and decision making, while digital traceability has a modest impact. The results also show that digital platforms significantly improve access to diverse, nutritious produce but their effectiveness is constrained by challenges such as low digital literacy and unreliable internet.

5.3 Recommendations

The study makes the following recommendations to enhance nutritional food security through digital supply chain optimization.

Strengthening of internet infrastructure whereby local authorities and private sector partners such as the telecom companies like Safaricom should install affordable community Wi-Fi hubs in Kibra's markets and residential areas to address respondents reporting unreliable internet connectivity, which limits effectiveness. These hubs should offer free or low- cost access to support platforms like Twiga Foods, Wasoko and Taimba, which are critical for timely delivery and market access.

Digital platform providers should implement low-tech, SMS-based traceability solutions such as text codes to overcome the low adoption of advanced tools like blockchain and IoT, which are hindered by the low digital literacy (no formal education) and awareness. These tools should be simple, requiring minimal data and compatible with basic mobile phones. This approach would enhance trust in produce safety, improving nutritional food security by ensuring quality.

Community organizations and NGOs should consider conducting mobile focused digital literacy workshops in Kibra, targeting low-literacy groups and older respondents to improve navigation of platforms like WhatsApp for digital market linkages and digital transparency. Training should be held in local languages at community centres, using practical demonstrations to teach platform usage. Digital literacy can increase market efficiency by 15-20% in low-income settings as highlighted by Aker and Mbiti (2015).

Platform developers should integrate concise nutritional information into mobile apps and SMS notifications to address the low score for nutritional information provision. This should use simple formats suitable for Kibra's low literacy users, such as icons and short Kiswahili texts, to guide consumer choices. Access to nutritional information can improve dietary diversity as noted by Owiti and Muthoni (2019). Simplified quality and return policies should also be established to improve regulatory clarity and trust. These standards should include clear guidance on produce freshness and refund processes to help reduce market disputes.

Stakeholders should support local farmer and trader cooperatives to integrate with digital platforms, leveraging existing mobile app usage to enhance digital market linkages and digital logistics integration. These cooperatives can aggregate produce and negotiate bulk deals on platforms like Twiga foods, Wasoko, Kyosk and Taimba, reducing costs for farmers and improving supply chain efficiency and thus improving market access.

5.4 Suggestions for Future Studies

Further investigation of digital supply chain optimization and nutritional food security is warranted based on the study findings, recommendations and conclusion. Future research should aim at exploring additional factors not examined in this study to validate and expand on the current findings.

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APPENDICES

Appendix I: Letter of Introduction

Ingolo Josphine,

The Management University of Africa.

Nairobi, Kenya.

Dear Respondent,

I am a graduate student at the Management University of Africa (MUA) currently pursuing my master's degree in business administration: Supply Chain Management and Logistics. As part of the requirement for completion of my studies, I am required to collect data for my research proposal to inform the development of my final thesis. My research topic is Evaluation of The Impact of Online Technologies in Addressing Supply Chain Challenges for Fresh Produce to Promote Food Nutrition and Security in Kenya. The target population are farmers, distributors, wholesalers, consumers and other stakeholders like technology and supply chain experts.

It is regarding this that I request for your time to help in responding to the attached questionnaire and or to the interview schedule. The information hereof will be used strictly for educational purposes and not any other reason whatsoever.

Thank you for your willingness to participate in this.

Yours faithfully,

Ingolo Josphine
Researcher.

Appendix II: Research Study Questionnaire

This questionnaire aims to collect data on the evaluation of the impact of online technologies in addressing supply chain challenges for fresh produce to enhance food nutrition and security in Kenya. You are kindly requested to take part in the study by responding to the items given in the various sections.

Background Information

1. What is your gender; Male (   )   Female (   )   Other (please specify)
2. What is your age group?

   18-24 (   )

   25-34 (   )

   35-44 (   )

   45-54 (   )

   55 and above (   )
3. What is your highest level of education?

   No formal education (   )

   Primary school (   )

   Secondary school (   )

   College/university (   )
4. What role do you play in the fresh produce supply chain?

   Farmer (   )

   Trader (retailer/ wholesaler) (   )

   Consumer (household) (   )

   Digital service provider (   )

   Logistics provider (   )

   Government/ regulatory body (   )
5. Which digital technologies have you used for fresh produce supply chain management? (check all that apply)

   a) E-commerce platforms (e.g., Twiga foods, Green-spoon, Wasoko, Taimba, Digi Farm)

b) Mobile applications (e.g., mobile money, soko yetu, market information apps)

c) Blockchain for traceability

d) IoT and logistics tracking apps (e.g., sensors for tracking produce)

e) Online communication tools (e.g., WhatsApp)

f) other (please specify) ____

SECTION B: Digital logistics integration

To the best of your knowledge and abilities, use the Likert scale in this section to rate the following opinions on Digital logistics intergration and Nutritional Food Security in Kibra Sub-County.

Where 5= Strongly Agree, 4 = Agree, 3= Neutral, 2= Disagree and 1= Strongly Disagree

	5	**4**	**3**	**2**	**1**
Digital logistics integration has improved delivery of fresh produce for me					
Using digital platforms has helped fresh produce reach me faster					
Digital platforms offer convenient options for receiving produce					
Logistics offered by digital platforms are cost effective					
Digital platforms provide clear information about the expected delivery of the fresh produce					
The digital platform I use for fresh produce logistics are reliable					
Using digital platforms has reduced the effort required for me to obtain/distribute fresh produce					

SECTION C: Digital market linkages

To the best of your knowledge and abilities, use the Likert scale in this section to rate the following opinions on Digital market linkages and Nutritional Food Security in Kibra Sub-County

	5	4	3	2	1
Buying fresh produce online is easier than going to the market					
Digital platforms make it easier to compare prices of fresh produce					
Digital platforms give me enough information to decide about buying/selling					
Buying/selling fresh produce online is easy and quick					
Digital platforms offer easy ways to pay for fresh produce(M-pesa)					

SECTION D: Digital traceability

To the best of your knowledge and abilities, use the Likert scale in this section to rate the following opinions on Digital traceability and Nutritional Food Security in Kibra Sub-County

	5	4	3	2	1
I am aware of digital traceability tools (e.g., QR codes, labels) that provide information about the origin or quality of fresh produce					
Digital traceability tools make me feel more confident about the safety and quality of fresh produce I buy					
Access to traceability information (production date, farm location) influences my decision to choose fresh produce					

Digital traceability tools are easy to use and understand when purchasing fresh produce					

SECTION E: Digital transparency and information sharing

To the best of your knowledge and abilities, use the Likert scale in this section to rate the following opinions on Digital transparency and information sharing and Nutritional Food Security in Kibra Sub-County

	5	**4**	**3**	**2**	**1**
Digital platforms give clear information about how good the fresh produce is					
Using digital tools makes buyers/ sellers trust each other more					
Digital platforms make information about fresh produce easier to find					
The information online helps me make better choices about fresh produce					
Digital platforms make it easy to give feedback about fresh produce					
Digital platforms have rules about fresh produce quality and returns					

SECTION F: Nutritional food security

To the best of your knowledge and abilities, use the Likert scale in this section to rate the following opinions on Nutritional Food Security in Kibra Sub-County

	5	4	3	2	1
Digital platforms help me access a wider variety of nutritious fresh produce					
Digital platforms have increased the amount of different healthy fresh produce my household eats					
Digital platforms make nutritious fresh produce more affordable for me					
Digital platforms connect me as a consumer/vendor with sources of nutritious fresh produce I didn't know about before					
Digital platforms give information about the nutritional value of the fresh produce					
Using digital platforms has positively impacted the nutritional quality of the fresh produce available in my household					

Appendix III: Interview guide

Introduction

Section 1: Background information

Name:

Role:

Organization:

Stakeholder:

Years of experience:

Section 2: Role in the fresh produce supply chain

a) Can you describe your role in the fresh produce supply chain?
b) How do you interact with other actors in the supply chain?
c) What are your main responsibilities and activities related to fresh produce?

Section 3: Challenges in the fresh produce supply chain

a) What are the biggest challenges you face in the fresh produce supply chain in Nairobi County?
b) How do these challenges affect your ability to operate effectively?
c) In your opinion, how do these challenges affect the availability, affordability and quality of fresh produce for consumers?
d) How do these challenges affect vulnerable populations or those in informal settlements?

Section 4: Digital technology adoption and awareness

a) What digital technologies are you currently using in your work related to fresh produce supply chain? (e.g., mobile phones, online platforms, inventory management system)
b) What other digital technologies are you aware of that could be used in the fresh produce supply chain?
c) What are the main benefits you have experienced from using digital technologies?
d) What are the main barriers to adopting digital technologies in the fresh produce supply chain? (e.g., cost, digital literacy, access to technology, poor infrastructure)

Section 5: Potential of digital technologies

a) In your opinion, what is the potential of digital technologies to address the challenges in the supply chain in Nairobi County?
b) How can digital technologies be used to improve efficiency of the supply chain (e.g., reducing losses post-harvest, improving logistics, streamlining transactions)
c) Can digital technologies help improve the livelihoods of farmers and other actors in the supply chain? If so, how?
d) How can digital technologies empower consumers to make more informed choices about fresh produce?

Section 6: Impact on nutritional food security

a) How do you think digital technologies can improve the accessibility of nutritious fresh produce for consumers in Nairobi County?
b) Can digital technologies play a role in making fresh produce more affordable, especially for the low-income households? If so, how?

c) How can digital technologies enhance the stability of the fresh produce supply and reduce price volatility?
d) In what ways can digital technologies improve the quality and safety of fresh produce in the supply chain?

Section 7: Digital technology interventions: digital logistics integration

a) How could digital platforms improve the transportation and delivery of fresh produce? (e.g., route optimization, real time tracking)
b) What are the potential benefits of using digital tools for inventory management and storage?

Digital market linkages

a) How can digital platforms better connect farmers with buyers and consumers? (e.g., price information systems, online market places)
b) What is the role of digital technologies in empowering smallholder farmers and increasing their market access?

Digital traceability

a) How can digital traceability systems improve transparency and accountability in the fresh produce supply chain?
b) What are the benefits of traceability for ensuring food safety and quality?

Digital transparency and information sharing

a) How can digital platforms improve information flow and coordination among supply chain actors?

Appendix IV: NACOSTI Permit

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