

Nexus of Cold Chain Logistics Distribution Routing and Scheduling for Safe Fresh Tomatoes Distribution in Nigeria

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Abstract

The safe and effective delivery of fresh Tomato products is critical for maintaining the quality of fresh tomato products and for decreasing the post-harvest losses experienced in the value chain. It also enhances the tomato products' early delivery quality preservation and shelf-life extension. However, globally huge fresh tomato waste and losses are annually being recorded as a result of poor delivery practices. In Nigeria, the tomato value chain product losses have been on the rise annually about 40% to 50% due to poor distribution practices. This paper investigates the nexus between cold chain logistics vehicles routing and scheduling and how it impacts the safe distribution of fresh tomato products in Nigeria. This will encompass the identification of relevant literature on optimal routes, selection for appropriate cold chain logistics vehicle routes, and schedules planning, the paper will also investigate the factors responsible for the inefficiencies of cold chain vehicle routing and scheduling operations geared towards promoting cold chain logistics performance and sustenance in the tomato value chains in Nigeria. The methodology employed for this study entails the conduct of a semi-structured interview and focus group discussion to generate data, analyzed using thematic analysis. The results of the study show that infrastructure limitations, insecurity challenges, absence of well-defined supermarket channels, regulatory challenges, weather challenges, transportation challenges and market demand uncertainties impede effective vehicle routing and scheduling practices which have a negative impact on the fresh tomato distribution in Nigeria. These findings suggest that poor routing and scheduling practices can slow the growth of cold chain logistics and increase the risk of tomato product losses and waste, thus increasing the rate of food insecurity in Nigeria. This study's findings will help to give transport planners relevant information that will guide them in policy formulation to mitigate against the imminent food insecurity challenges experienced in the Tomato value chains in Nigeria during distribution operations. Hence, future studies could focus on finding

the economic implication of vehicle routing and scheduling on cold chain business growth and efficiency in Nigeria.

Keywords: Cold Chain, Logistics, Vehicle Routing, Scheduling, Distribution, Fresh Tomato Products

Introduction

The physical distribution of fresh tomato products plays a critical role in ensuring the availability and quality of these perishable products to consumers in the market space (Cassou et al., 2020; Gromko & Abdurasulova, 2018). In Nigeria, the distribution of tomatoes from production origins in Kano to major consumption hubs in Lagos State is important to its availability and affordability. Kano, located in the north-west region of the country, serves as one of the major tomato production centres, while Lagos State located in the south-west is a bustling commercial and economic hub with a high demand for fresh tomato produce, and serves as the main distribution destination in the value chain. Furthermore, according to Mohan et al (2023), based on the highly perishable nature of fresh tomatoes the ripened fruit needs to be kept at a temperature of 10 to 15 degrees Celsius, and the relative humidity is to be held at 80–90% in the postharvest stages where cold chain logistics are essential in extend the shelf life of fresh goods and reduce the amount of waste generated. Similarly, Akram et al (2023) cold chain logistics operations refer to a series of temperature-controlled operations starting at the farms and ending with final consumers. Thus, Cold chain logistics operations keep all fresh tomato products at an ambient temperature and sealed through thermal and refrigerated packaging and storage, especially during product transportation distribution operations. However, according to Aderogba & Adegboye (2019), the safe and effective distribution of fresh tomatoes is a critical challenge in Nigeria, given the perishable nature of the product and the country's diverse geography and infrastructural limitations which is currently classified globally as 132 among 138 nations and these limitations restrict the growth of trade within the value chains in the country. Thus, the limited access to basic transportation infrastructure for product distribution has led to the loss of about 50% of the tomatoes produced in the country (Abdul et al., 2020b; Ayomide et al., 2019). This occurs because the poor road transport that links northern Nigeria with the south-west through various states is heavily affected by the presence of potholes, mud, bumps, untied road and gravels, thus very harmful tomato fruit while in transit (Elijah, 2021). Similarly, according to Cassou et al (2020) the absence of cold chain logistics at the upstream level of the tomato value stream operation couple with the nature Nigeria's road density which is low results in approximately 75% of Nigeria's rural population without access to an all-season road network. Farmers already feel the impact of inadequate rural infrastructure, which manifests itself in high transportation costs while reducing farmgate product prices but increasing the market prices. Furthermore, the absence of cold chain logistics technology for products cooling and the breakdown of vehicles and the baskets containing tomato while on transit lead to losses and high marketing cost for wholesalers, retailers and consumers (Cassou et al., 2020; Victor & Elejo, 2023). Therefore, understanding the distribution patterns of fresh tomatoes from Kano to Lagos State is vital for optimizing the supply chain, reducing post-harvest losses, and ensuring consistent availability of quality tomatoes to meet consumer needs. The transportation and logistics processes involved in the distribution of fresh tomatoes from Kano to Lagos State are complex and multifaceted. Multiple actors, including farmers, wholesalers, retailers, and transportation companies, are involved in this intricate network. Each stage of the distribution process, from harvesting to final delivery, requires careful

coordination and efficient handling to preserve the freshness and quality of the tomatoes. Thus, according to Abdul et al (2020b); Ugonna et al (2015b), the distribution patterns of fresh tomato products encompasses various aspects, including the routes and modes of transportation employed, storage and preservation facilities utilized, and the challenges encountered along the way. Hence, infrastructure limitations, such as road conditions, inadequate storage facilities, and the unreliable cold chain logistics systems, contribute significantly to post-harvest losses and quality deterioration of tomato products. Furthermore, supply chain inefficiencies cause markets fluctuations and quality control issues which pose significantly challenges to effective distribution of fresh tomatoes in Nigeria. Thus, this study objectives are as follows;

1. Investigates the nexus between cold chain logistics vehicles routing and scheduling
2. investigate the impact of cold chain logistics vehicle routing and scheduling on safe fresh tomato product distribution in Nigeria.

Study Conceptual Framework

The Figure 1 show the conceptual framework of the study. It shows the flow of the paper and the topical issues that this study will be discussing in understanding the nexus of vehicle routing and scheduling, its effects on effective distribution of fresh tomato products using cold chain logistics operations. The topical issues that will be discussed include; effective distribution, divided into to two main categories effective scheduling and routing. The effective routing process include; Transportation planning, Fleet selection, Route selection, The challenges. Similarly, the effective scheduling practices, schedule time planning, scheduling expectation, scheduling challenges.

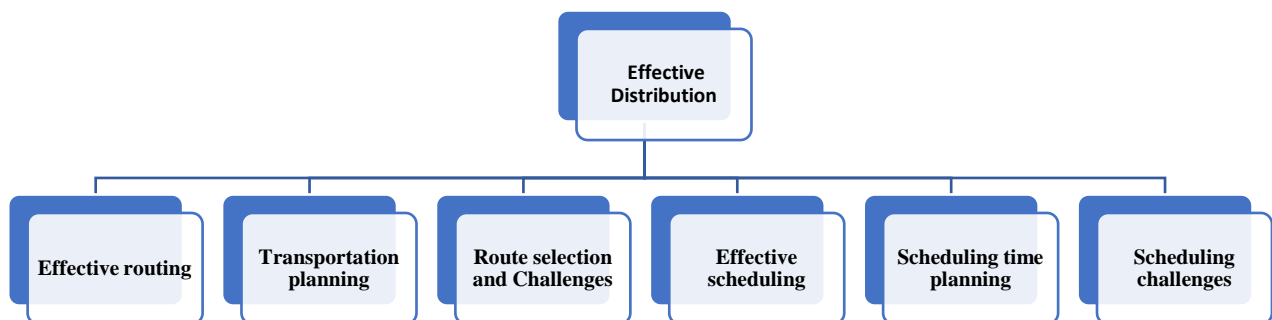


Figure 1. Conceptual framework

Methodology

The qualitative study conducted a focus group discussion (78) participants who are farmers, wholesaler, retailers and transporters in the tomato value chains in Kano (Bagwai, Danbata, Garin Mallam) and in Lagos (Agege Ile Epe markets and Mile 12 markets.) to arrive at the finding for this study and thematic analysis method was used to generate codes, through the open coding method and the axial coding, this code categories were derived from the initial open coding. The axial coding was also selected through extended codes and related code points. A lot of related phrases from the dataset were selected to describe the study themes and sub-themes. Finally, selective coding was done to derive the final study themes for the study. The study also aims to explore the nexus of fresh tomato product cold chain logistics distribution routing and scheduling and its impact on the safe distribution of fresh tomatoes in Nigeria. This paper will delve into various themes to comprehensively examine the current state of cold chain logistics distribution for fresh tomato in Nigeria.

Results and Discussions

Cold Chain Logistics Distribution

Cold chain logistics operations in the fresh food value chains are specially designed specifically to maintain the quality of perishable foods and to keep perishable these fresh fruits like tomatoes at the appropriate temperature and humidity to prevent them from becoming contaminated by harmful micro-organisms and it begins at the farm level and extends all the way to the consumer. Pre-cooling facilities, cold storage facilities, refrigerated carriers, containers, packaging, and track-and-trace measurement tools are all part of the standard parties involved in the supply chain, the businesses serving them, their customers, and the general public can be realised if the is managed efficiently (Akram et al., 2023). Thus, the effective cold chain logistics distribution means having seamless distribution that will ensure safe and quality transshipment of products from their origin source to desired destination. These can only be achieved through distribution planning which is a very vital activity of the tomato value which links products with the market. Furthermore, according to Kellner (2021) the fast-moving consumer goods industry where fruits like tomato belong high stock turnover and high-volume sales rely on effective product distribution and this make distribution activities essential. However, currently in Nigeria tomato value chain service providers such as farmers, wholesalers, retailers and transporters complain that the distribution operation in the value chain is very hectic and cumbersome given the number of eminent challenges that are experienced in the value chain as a result of poor routing and scheduling practices that lead to poor distribution operations. Based on the focus group discussions conducted, Figure 2 shows some of the eminent distribution challenges experienced by logistics service providers within the tomato value chain that affect their routing and scheduling decisions. It also shows the challenges of vehicle routing and scheduling affecting the tomato value chain in Nigeria (Kano and Lagos trading corridors). These factors include bad road infrastructure, poor packaging practices, absence of cold chain logistics technology, poor storage practices, bad weather, insufficient vehicles and harassment from law enforcement officers, insecurity challenges, market demand uncertainties, absence of defined supermarket channels.

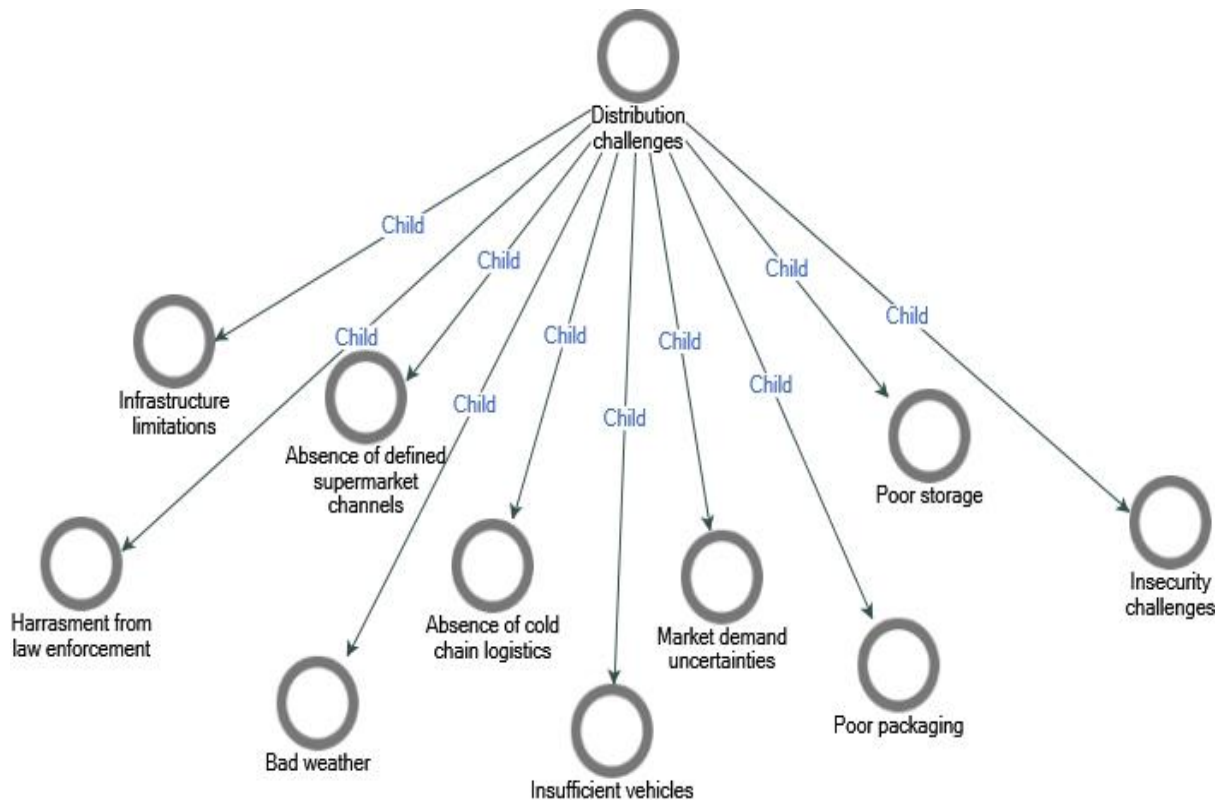


Figure 2 The distribution challenges that affect tomato product routing and scheduling operations.

Some of the participants reported the distribution operations as thus

FGD1 RQ1 P2 It takes 2 to 3 days for tomato products from Kano to arrive at Lagos destinations. While the turnaround for the drivers is 4 days maximum.

FGD3 RQ1 P4 The tomatoes are distributed through the use of road transport vehicle such trucks, trailer tankers and J5 for long distance markets like the once in Lagos but for the village community markets products are distributed using mini pickup trucks, motorcycle, tricycle.

FGD4 RQ3 P5 Tomato distribution has a lot of problems that occur due to bad roads infrastructure, lack of cold chain logistics refrigeration for product storage while on transit for further distribution and it causes delay in distribution and also leads to loss of potential long-term customers.

FGD5 RQ2 P4 mini trucks that can carry a 50to 70 baskets to the markets successfully. Other means of transportation vehicles used are mostly used for long distance travel. These vehicles are the J5, 3axle and 4 axle Trailer, the brand of this car is Volvo which is believed to be very strong, reliable and rugged

FGD5 RQ2 P5 due to insufficient vehicles transporters also load on fuel tankers which can carry about 80 to 120 baskets and tranship the tomato products to Lagos. These tanker trailers can carry about 80 full basket load od tomatoes. The J5, carries about 50 to 60 full baskets of tomatoes and while on transit the door of

the vehicle has to be open to provide for required ventilation and air for tomatoes product safe storage and safe keeping

FGD7RQ1 RP2 turnaround for the drivers is 4 days maximum. So, at peak period a truck can make two supplies in a week.

FGD9 RQ3P3 bad roads infrastructure and it causes delay in distribution and also leads to the loss of potential long-term customers. Also, the obvious absence of cold chain refrigerated storage for precooling and the absence of cold chain logistics refrigerated haulage truck for tomatoes product distribution affect product quality, freshness.

Table 1 Themes, sub-themes and description representing the distribution challenges of routing and scheduling in the tomato value chains in Nigeria.

Main Themes	Sub-theme	Description
Infrastructure Challenges	Absence of Cold Chain Technology	This refers to the insufficient and eminent absence of Lack of proper temperature-controlled logistics, this affects the quality and safety of perishable tomato products during storage and transportation
	Poor Packaging Practices	These inefficient packaging methods used such as raffia baskets result in huge product damage, spoilage, and increased risk of losses and waste during transportation.
	Bad road infrastructure	This refers to poorly maintained roads that hinder the smooth flow of and movement of tomatoes, leading to delays, damage, and increased transportation costs
	Poor Storage Practices	This refers to the obvious absence of cold chain facilities in the tomato value chain. Thus, leading to tomato product timely deterioration, spoilage, or damage due to improper handling, stacking, or environmental conditions.
Weather challenges	Bad weather	This refers to effect of severe weather conditions such as storms, floods, or extreme temperatures affecting

Main Themes	Sub-theme	Description
		transportation and storage, leading to disruptions and delays.
Transportation Constraints	Insufficient Vehicles	This refers to the insufficient and Inadequate availability of vehicles for transportation and distribution of tomato product from their origin of production in kano to the markets in Lagos, causing delays, increased lead times, and inefficiencies in the supply chain.
Regulatory Challenges	Harassment from Law Enforcement Officers	These refers to the problems associated with regulatory compliance and corruption practices, resulting in delays, increased operational costs, and disruptions in the supply chain.
Absence of defined supermarket channel	Supply chain challenges	This has to do with lack of a well-defined supermarket channel, a situation that shows there is no well defined network that links suppliers from markets to supermarkets chain within a tomato value chain, market and industry.
Market demand uncertainties	Competitive dynamisms of markets	Market demand uncertainties refer to the unpredictable and fluctuating nature of consumer demand for products or services in a given market. These uncertainties can be influenced by various factors such as economic conditions, consumer preferences, external events, and technological changes.
Insecurity challenges	Impediments to products safety	These refers to all unsafe acts and situations that lead to operations vulnerability and high-risk situations. It ranges from personal and community safety to national and global security issues.

Principle of Effective Distribution

Effective distribution entails a lot of planning and coordination. The focus of cold chain logistics fresh tomato distribution operations is to effectively provide an ambient refrigerated temperature that will link the fresh tomato product from farms to the markets without deterioration and contamination (Cassani & Gomez-Zavaglia, 2022). Hence, the development of cold chain logistics technology innovations is critical for the effective distribution of fresh

tomato products and must be carried out by the use of good packaging and transportation tools, rigorous temperature control requirements, continuous process monitoring for effective product tracking and tracing, and anomaly alerts which must be put in place to avoid mishaps (Li et al., 2022). Furthermore, the utilization of cold chain logistics operation for fresh tomato distribution reduces operations risk will guarantee product quality and reduce tomato product losses (Cassou et al., 2020).

Effective Routing

The increasing global emissions of greenhouse gases and environmental pollutants from road freight distribution has sparked a growing interest in studying Vehicle Routing and Scheduling Problems (VRSPs) with environmental considerations (Raeesi & Zografos, 2020). This entails transport planning, fleet selection, route planning. Thus Liu et al (2021) argued that the criteria of sustainable development may be met by efficiently reducing the carbon emissions of the whole supply chain system through the optimization of the cold chain logistics distribution channel. The final link in tomato value chain cold chain logistics operations is the distribution of fresh products safely, and the distribution route optimization is a crucial component of distribution optimization. The cost and profit of distribution are significantly impacted by the rationality of the distribution route chosen during the distribution process.

Optimization techniques for determining optimal routes

The Optimization techniques for determining optimal routes selection for transporting fresh tomatoes from farms to markets or processing facilities. Consideration of temperature control and storage requirements during transportation. In Nigeria one of the primary difficulties logistics service providers are confronted in the daily discharge of their operations and services is transportation of their perishable products. This is a great source of concern. Every day, a huge amount of money is spent on gasoline, machine maintenance for the transportation, distribution and delivery of goods and service to meet customer expectation. However, in order to achieve effective and efficient fresh product from farm to market logistics service providers expertise is required (Ibrahim et al., 2019). More so, in today contemporary times computerised techniques are frequently used to solve transportation problems. This results in a 5% to 20% reduction in transportation costs (Ibrahim et al., 2019).

Thus, this study also reveal that vehicle routing problems (VRPs), also referred as the truck dispatching problems are commonly encountered by businesses ventures such the cold chain logistics industry where service providers are saddled with complex operations where it is always of primary interest to find reliable means for obtaining optimal routes to different locations especially based on fuel and truck drivers' wages and salaries as stated by (Oluyinka et al., 2018). The essence of finding an optimal route for tomato product distribution in the tomato value chain is to ensure that each and every customer is served once and every vehicle is loaded according to its capacity and not more (Ibrahim et al., 2019). Thus, a classical Vehicle routing planning (VRP,) for instance, determines an optimal route for a set of vehicle located at a depot; convening a product to a number of customers at different locations (Oluyinka et al., 2018).

Transportation Cost for tomato products in Nigeria Kano- Lagos route / distribution Cost

The transportation of tomato product on the Kano -Lagos trading corridor in Nigeria is mainly carried out through the use of road transport mode which utilizes, lorry, Mini buses, J5

vehicles and fuel tankers. These vehicles which are trucks, tankers and J5 vehicle, mini vans are used in distributing these tomato products from suppliers to customers along the Kano Lagos corridor. However, the cost by vehicle vary according to the type of vehicle used from Kano to Lagos and the load capacity. The cost of transport tomato product freight rate for a truck load is N250,000, tankers freight rate is N80,000 and while the J5 freight rate is N100,000 to N120,000. The product loading point is dependent on the farm location, buying and selling agreements, in the different towns like; Bagwai, Danbata and Garin Mallam where the study was conducted. However, the common practice is that most products are being loaded at the market square after being wrapped in a raffia basket which vary from 15 to 25 kg.

Transportation Planning

Transportation plays a vital role in the actualization of everyday activities and possibilities thus, it is an integral aspect of our existence which promote economic, social growth and personal mobility (Colicchia et al., 2017). This study also agrees with this stance and also highlights that the planning process entails looking out for the best and safe transport mode option for movement of freight from the origin to the consumption destination through a mode selection. Thus, Li et al (2022) argued that the quality of fresh fruits like tomato is highly dependent on the delivery time;. Thus, according to Goswami et al (2020) transport planning influences performance parameters of sustainable freight operations at all level including strategic, tactical, and operational. This is by reviewing their potentials. Although, there is rail transportation network which is expected to be a more viable option, however, the rail system is still struggling with inefficiencies in the Kano, Lagos trading corridor, thus the Potential for rail links between Kano and Lagos although available but the distribution services are low and ineffective. Thus currently, the transshipment of tomato products from northern to southern Nigeria is mainly done through the use of road transport mode (Gromko & Abdurasulova, 2018).

Transporting Fresh Tomatoes from Farms to Markets

Generally in a typical farming community, traders collect tomatoes products from rural areas and sell them in the city throughout the year according to (Chaboud & Moustier, 2021). In Nigeria majority of the tomatoes consumed are grown in the northern part as of the country mapped by the study as Kano (Bagwai, Danbata, and Garin Mallam communities) then transhipped to the southern part of the country Lagos (Agege Ile Epe and Mile 12markets) where the dominant markets for these products exist. The freighting operations usually take place at night time to ensure smooth flow of traffic. Thus, according to Tang (2022) cold chain logistics vehicles are expected to maintains an ambient temperature range for fresh food during product distribution in order to slow these biological decay processes and to ensure safe, high-quality fresh tomato product distribution and delivery to customers. The absence of cold chain logistics operations has led to huge losses and wastages of tomatoes products being experienced in the tomato value chains (Odeyemi et al., 2021; Suleiman, 2021). Furthermore, regardless of the marketing channel, the common practice in Nigeria is that tomatoes are transported by truck (un- refrigerated) and always kept open for free air circulation to maintain an ambient temperature during transits from the farms to the markets and from the northern market to the southern markets. This practice has causes product losses annually of 50% in the tomato value chain. Hence the Importance of cold chain logistics operation is critical towards ensuring the preserving, guaranteeing the quality and safety of

perishable fresh tomatoes from suppliers to their consumers (Liu et al., 2023). However, absence and obsolete nature of road transport infrastructure such as good roads, bridges, road signs, weigh bridges and network infrastructure in Nigeria and the absence of full government policies and initiatives in promoting cold chain logistics has impeded the growth of cold chain logistics operations in the tomatoes value chain and this has also affected the distribution routing and scheduling in this value chain (Cassou et al., 2020). Figure 3 below shows the routes utilized for fresh tomato distribution from kano to Lagos and their eminent challenges.

The figure 3 below shows the routes utilized for tomato product distribution from Kano to Lagos and their eminent challenges which range from bad road infrastructure problems such as potholes, traffic congestion, insecurity challenges associated with banditry, accident blind spot and black spot.

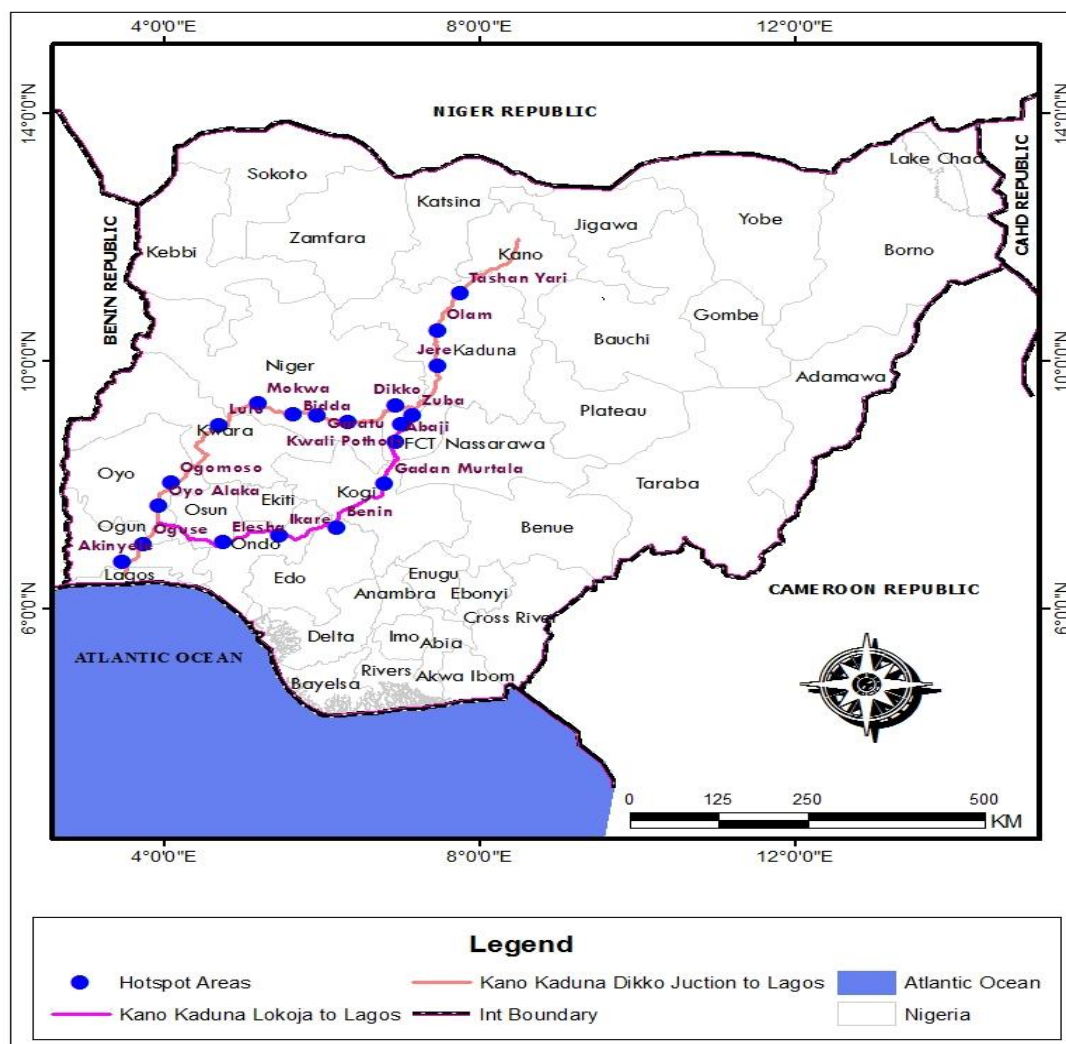


Figure 3: Kano to Lagos Tomato distribution routes hotspot areas.

Table 2 below shows the different hotspot challenges characteristics visible along the distribution route for fresh tomato distribution from Kano to Lagos route. These challenges are; traffic congestion, banditry, accident black spot, robbery, potholes and accident blind spot. This affects the travel time, waiting time, lead time and turnaround times for distribution.

Table 2

Kano to Lagos tomato products distribution routes, states and their characteristics

S/No	State	Hotspot Areas	Characteristics
1	Kano	Nil	Nil
2	Kaduna	Tashan Yari, Rijana, Jere	Banditry, Traffic congestion, accident black spot, blind spot
3	Abuja	Abaji, Kwali	Potholes, black spot
4	Niger	Dikko Juction, Bidda, Tafa, Mokwa, Garatu, Lambata,	Potholes, Trailer traffic congestion
5	Kogi	Gadar Murtala, Kabba	Potholes, accident black spot
6	Kwara	Luru, Jeba	Traffic congestion, accident black spot
7	Benin	Benin City, Obilo	Robbery
8	Ogun	Oguse, Elesha, Shagamu	Potholes, accident black spot
9	Osun	Ikare	Potholes, blind spot
10	Oyo	Ogbomosho express, Oyo Alaka, Akinyele	Traffic congestion, accident black spot

Figure 4 below shows the distance covered during the distribution of tomato from Kano to Lagos.





Figure 4. showing tomato product loading in the different types of vehicles used for tomato distributions in Nigeria. These vehicles include; Trailers, fuel tankers and mini vans in Grin Malam at Kadawa market.

Figure 5 shows that the distance travelled from Kano to Lagos route. The distance is about 1,195 km approximately. Thus, based on this long-distance travel from Kano to Lagos the tomato products are exposed to different atmospheric conditions that affect the freshness of the tomato being transported which are usually packaged in raffia baskets and this result in huge product losses during distribution operations.

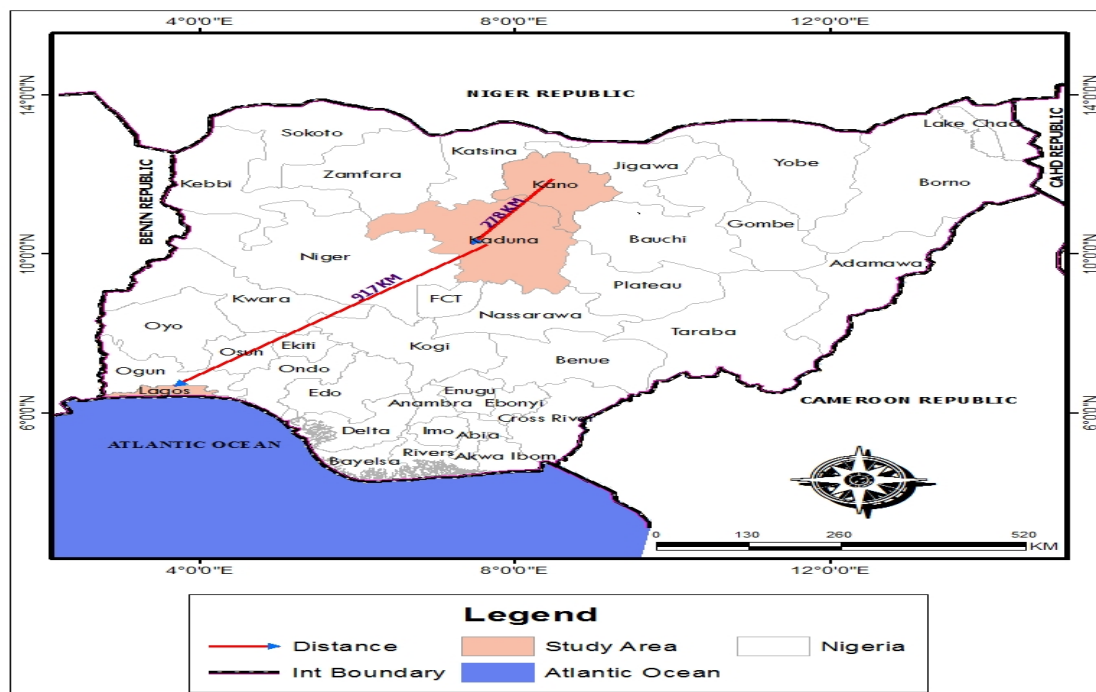


Figure 5. Kano to Lagos tomato distribution routes Distance per kilometre travelled.

Vehicle Route Selection

In Nigeria basically the distribution of tomato product are done using the road transport mode ,thus the appropriate selecting of vehicle routing has an extensive influence and role to improve the economic interests and appropriateness of logistics planning (Mohammed et al., 2017). Route selection is a serious component of the decision making and it influences the

distribution plannings dependent but is dependent on factors such as on factors such as distance, cost and safety and security and last mile product delivery. This is further corroborated by findings of (Cassou et al., 2020).

Factors Influencing Vehicle Routing Decisions

The routing decision for distribution is very critical in the tomato value chain. The route selection is more very critical towards maintaining product freshness, safety and integrity. The routes utilized for the tomsato products distribution determines the level time and value of service delivery offered to the customers. The time associated with product distribution such as lead time and turnaround time for product distribution is a very component that determines the efficiency of the tomato value chain operations. Thus, there are numerous factors that play a vital role in the selection of the routes utilized for product distribution, these factors are as follows; distance, road conditions, traffic congestion , weather and security challenges this is further corroborated by findings of (Ani et al., 2022; Mohammed et al., 2017). Figure 6 below shows the factors that influence distribution routing and scheduling in Nigeria. These challenges range from distance travelled, weather, insecurity on the highways, bad road conditions traffic congestions.

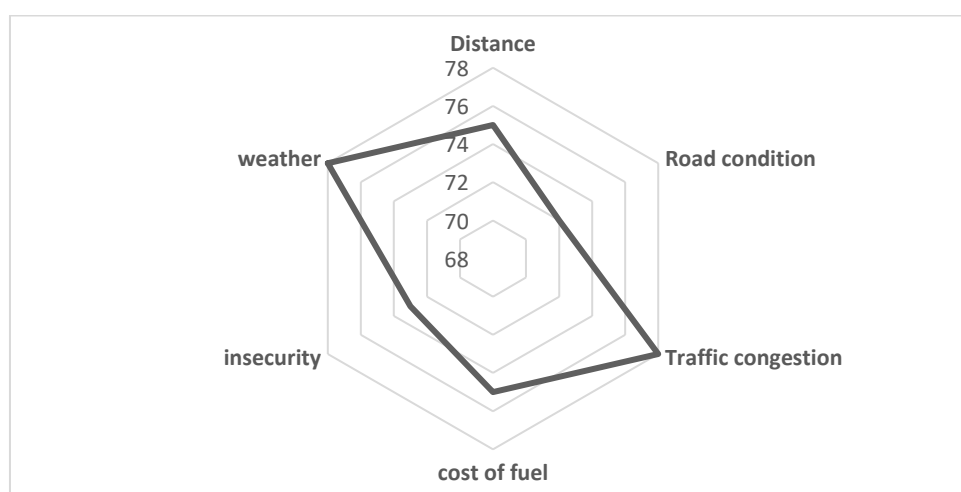


Figure 6. showing the factors that influence distribution routing and scheduling challenges in the tomato value chain.

Effective Vehicle Scheduling

Distributing scheduling have to do with allocation of appropriate timing for vehicle movement and dispatch, the turnaround time, lead time and waiting time have to be considered. Thus, figure 7 show the factors that cause effective scheduling as delivery datelines, demand fluctuations, capacity constraints, supply chain viability, regulatory compliance weather conditions, infrastructure and logistics organization, labour and skill availability and technology driven data sight. The Scheduling methods for efficient utilization of cold chain logistics resources, such as refrigerated trucks and storage facilities is very critical to the overall performance of the cold chain system. In view of the current traffic congestion and insecurity challenges vehicle scheduling has become a very important activity in the tomato value chain in Nigeria, that ensures products safe arrival. Most tomato vehicle leave their origin at night to arrive their destination at the early hours of the morning after a whole day's trip. Although, Onyeneke et al (2023); Ugonna et al (2015b); Onyeneke et al (2023); Ugonna et al (2015a) argued that infrastructure deficit cause tomato waste in the tomato value , these

studies did not emphasize the need to employ cold chain logistics as a viable option product losses recorded in the value chain. thus, this study insists that Cold chain logistics distribution scheduling for fresh tomato is important and the distribution should involve proper planning and managing the transportation and storage of tomatoes in a way that ensures they remain at optimal temperatures throughout the supply chain. This is crucial for preserving the quality and safety of fresh produce. The factors that cause effective scheduling are listed in figure 6 below.

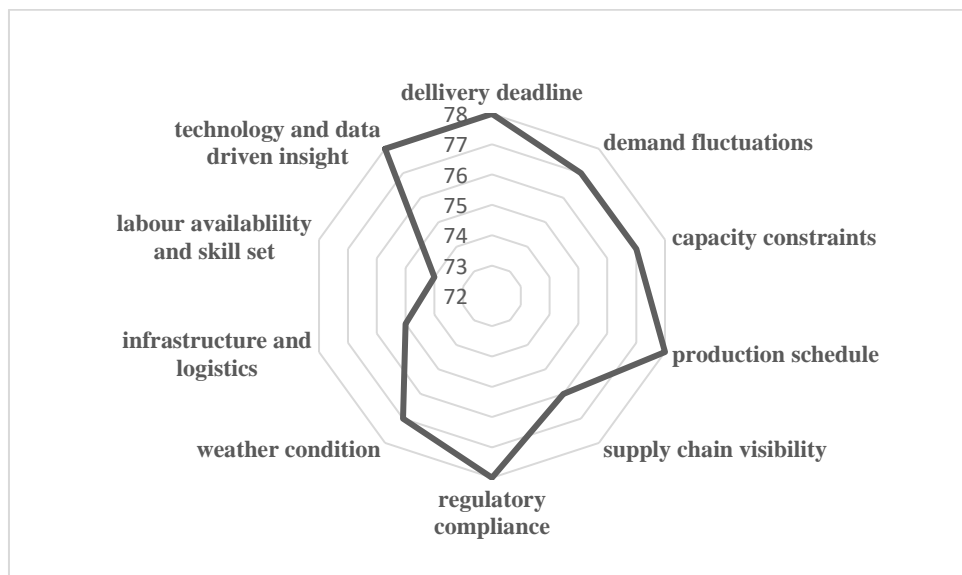


Figure 7 shows the factors that affect vehicle scheduling in the tomato value chains in Nigeria.

Route Planning for Transportation Network

The routes make up the different nodal location network for all road network. A route is a link between two spots which are inside a large network. The setting of a network comes from various strategies of access and modes which have better advantages than others. A transport network can either be a permanent track or a scheduled service and it can cover various types of links among points where movements can take place according to Rodrigue (2013). This study agrees with the findings of Rodrigue (2013) and these two types of transport networks are shown in figure 8 which shows that Point-to-point transportation has always been used for its advantages in time and delivery control. It has a great advantage in flexibility and just-in-time delivery. Transport hub is a newly developed network structure which increased transport flexibility. Spokes are liner services between terminals and hubs. Hub-and-spoke networks often lead to a better efficiency of transportation. The hub-and-spoke system is designed to merge small flows of materials moving in different directions which were represented by arrows in Figure 8.

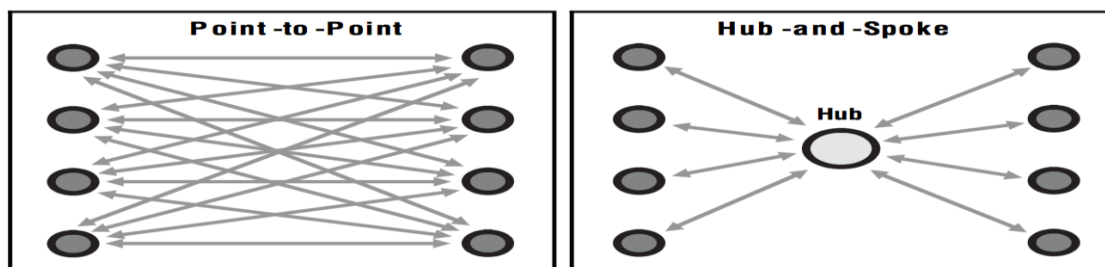


Figure 8 Transport Networks, (Rodrigue 2013, Comtois & Slack, 2006)

Figure 9 shows the distribution hub and spoke network. The spoke represents the route networks while the hub represents the central destinations. The hub and spoke integration reorganise the transportation system which allows integration in some transport distances. However, according to Comtois & Slack (2006); Rodrigue (2013) with the reduced transport distance and economy of scale, costs for every single network link is lower, and the total costs too is made lower. This study also agrees with Rodrigues findings that the transport network represents the routes and it helps in achieving the movements. It creates connection within the different areas of the tomato value chain transportation network and helps in ensuring the physical transfer of tomato products from farm to markets through information sharing and fluctuations in a fast and orderly manner. Figure 9 below shows the four (4) major routes being utilized for tomato product transportation and distribution from Kano to Lagos State.

The Figure 10 below shows the major routes being utilized by transporters for onward distribution of tomato products from Kano to Lagos state Nigeria. The figure shows that their four major routes are being utilized for tomato distribution on this trading corridor. These routes are; 1st route; Kano, Kaduna, Birnin Gwari, Jeba, Shagamu, Ibadan, to Lagos. 2nd route; Kano, Kaduna, Dikko junction, Lambata Mokwa, Jeba, Shagamu, Ibadan, Lagos route, 3rd route; Kano, Abuja and Kogi, Okene, Obilo, Ijebu Ode, Shagamu, Ibadan, Lagos and the 4th route; Kano, Kaduna, Kogi, Kabba, Ilorin, Ijebu Ode, Shagamu and the Ibadan and Lagos routes. However, due to insecurity activities associated with banditry on the highway the first route which is the shortest routes have been now been abandoned by motorised thus leaving only three routes being utilized. the remaining routes also have some peculiarities of inadequate road furniture and infrastructure thus causing impediments to seamless transportation, distribution and delivery of tomato products to the consumers.

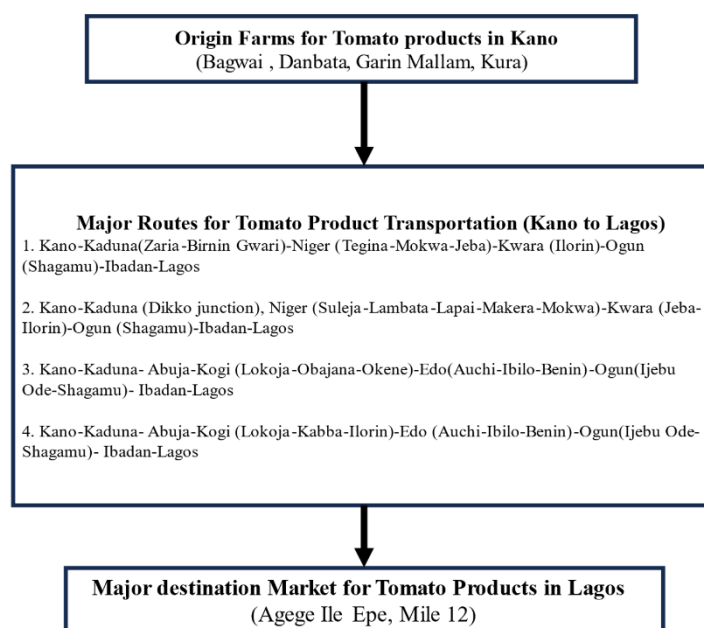


Figure 10 four major routes for tomato product transportation connecting Kano to Lagos state

Road Transportation

In Nigeria, the road mode of transport has expended a lot over the past 50 years for freight and passenger transportation. The best road transportation is freeway, which were often

used in artery transport. Some arterials are equipped with traffic signals as intersections which can make carriers stop for a while. According to Rodrigue (2013) road transport allows point-to-point transport and do not have economy of scale. Table 3 shows the advantage and disadvantages derived from road transportation services.

Table 3

Advantages and Disadvantages of Transportation Modes (Handfield, et al., 2009)

Mode	Advantages	Disadvantages
❖ Road	<ul style="list-style-type: none"> • High Flexibility • Good Speed • Good Reliability • Good for Just-in-time Delivery • Can negotiate rates 	<ul style="list-style-type: none"> • High Cost • Limited to Domestic or Regional Transportation • Cannot be Used for Large Volumes

Forms of Transportation Operations

There two main forms of transport operation in which highly been utilized in the tomato value chain. cut these form of transport operations cut across vast distances between hubs and depots is denoted by the term "line-haul." The second branch, known as last-mile delivery, involves the distributor picking up and delivering items. Last-mile delivery refers to short-distance transportation. This study was corroborated by the study Abdul et al. (2020a) which reiterated that usually, the form of transportation chosen is determined by service providers based on the nature of consumers consumption rate and pattern. Figure 11 below shows the different rate of tomato consumption across the tomato value chains in Nigeria. As shown in the figure, the consumption of tomato by region in Nigeria based on the geopolitical regions namely; North central, North east, North west, South east, South west and South -south.

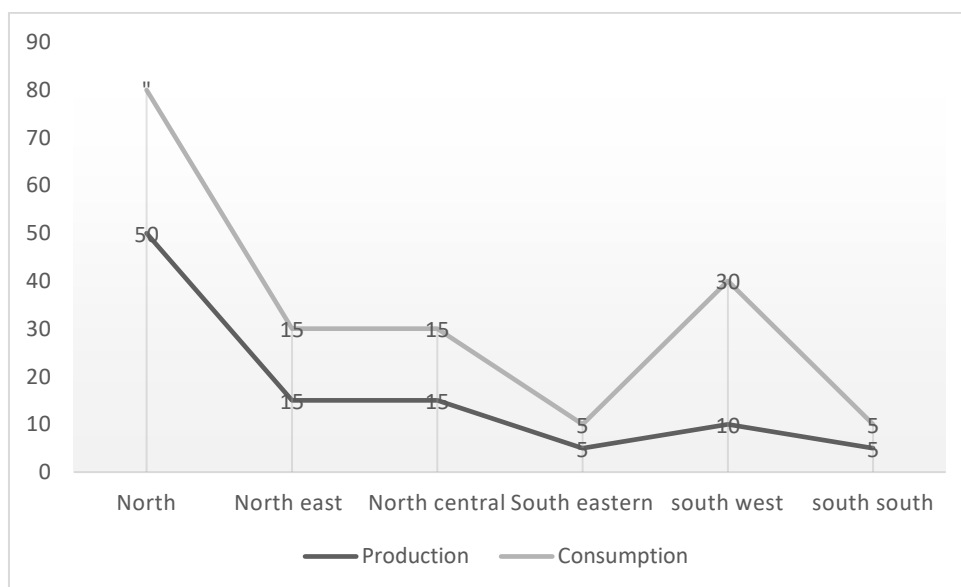


Figure 11 Different Rate of Tomato Consumption across the Tomato Value Chains in Nigeria.

Tomato Distribution Planning

The study findings reveal that tomatoes pass through many hands along this corridor as emphasized by (Cassou et al., 2020; Ugonna et al., 2015a). Farmers typically sell to local middlemen, who aggregate production and sell to traders. Traders make the trip to Lagos, where they sell to either wholesalers or directly to retailers. There are many markets in Lagos, but the largest is the Mile 12 market. Payment agreements between different actors vary, but it is not uncommon that farmers and middlemen in northern Nigeria are not paid until the traders return from Lagos on the next trip, after the tomatoes have been sold.

Scheduling times and Challenges in the Distribution Network

Scheduling time for product transshipment is very important in the tomato value so as to guard against product losses. In scheduling the appropriate for product transshipment, harvest time, waiting time and actual travel time determine the lead time for product arrival and the turnaround time for drivers return. However, the study reveals that infrastructure limitations, logistics, postharvest management, quality control, market demand variations, supply chain inefficiencies, and policy and regulatory matters affecting the distribution process and vehicle routing and scheduling practices and operations. This is further corroborated by findings of (Chukwu & Adibe, 2022; Olojede et al., 2019).

Safety Measures and Quality Assurance in Cold Chain Logistics

The study shows that it is very vital to maintaining proper temperature, humidity, and hygiene conditions throughout the cold chain. Maintaining proper temperature, humidity, and hygiene conditions throughout the cold chain is of paramount importance in the distribution of fresh tomatoes and other perishable goods as emphasized by study of (Cassou et al., 2020). This is because according to the study cold chain logistics is the series of processes and facilities used to keep products within a specified low-temperature range from production to consumption to maintain product quality.

Quality Control Procedures for Fresh Tomatoes

The study reveals that operations in the tomato value chain include the sorting, grading, and packaging quality control procedures for fresh tomatoes which also involve a series of steps to ensure that the tomatoes meet specific standards for size, colour, texture, and overall quality. This further agrees with the study of (Orjuela-Castro et al., 2022). This is described in Figure 12 below. The figure shows the criteria required by traders and service providers for tomato product sales, consumption and distribution. These attributes include; shape, weight, price, physical outlook.

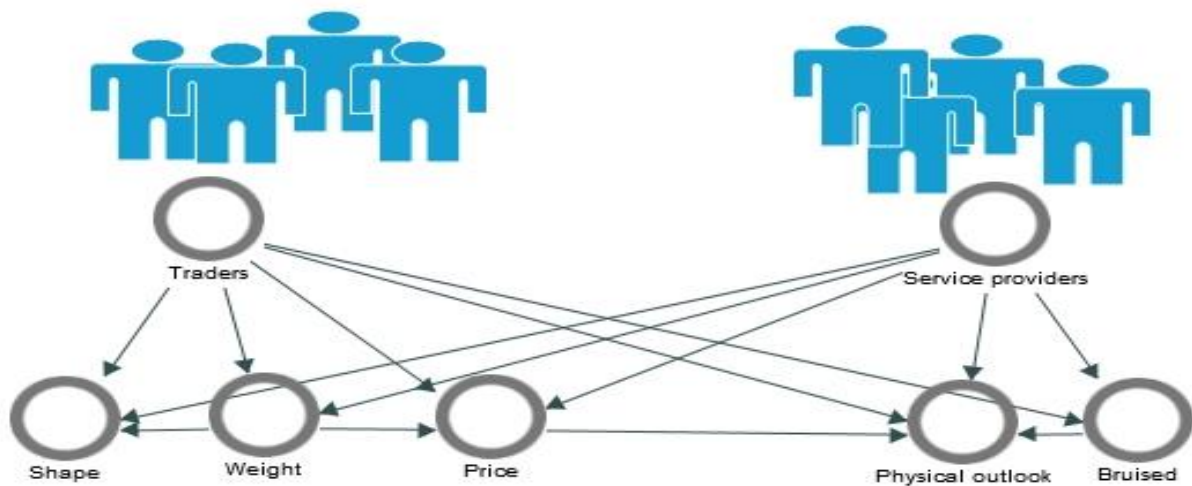


Figure 12: Tomato products quality attributes considered by trades and suppliers in the tomato value chain

Summary of Findings

The paper shows that there is high concern on the impact of cold chain logistics services on the nexus of routing and scheduling. Potential future developments and emerging trends in cold chain logistics for fresh tomato distribution A value chain, therefore, incorporates productive transformation and value addition at each stage. Also, in the value chain, at each stage, the product changes hand through service providers like farmers, wholesaler, retailers and transporter and when this occurs, transportation costs are incurred, and generally value is added through these activities. Tomato value chain has diverse activities including input supply, production, transportation, marketing, processing, distribution, retailing, and consumption. Thus, the main benefits of value chain are productivity value creations, profit creating, employment, and maintaining competitiveness and consumer satisfaction. Routing and scheduling challenges in the tomato value chain occur as a result poor infrastructure, like bad roads, route limitations route diversion due to insecurity challenges associated with banditry, and the obvious absence of cold chain logistics technology required for cooling products while they are on transit from Kano to Lagos.

It is evident that integrating optimization techniques in routing and scheduling can significantly enhance the efficiency and reliability of fresh tomato distribution. Leveraging real-time data, IoT devices, and blockchain technology can enable better monitoring, traceability, and transparency in the cold chain, ensuring compliance with quality and safety standards. Furthermore, stakeholder collaboration and capacity building initiatives are crucial for establishing an effective cold chain network, while also fostering economic growth and sustainability. The economic benefits of an optimized cold chain system are substantial, as it reduces post-harvest losses, increases market access, and improves overall profitability for farmers, suppliers, and retailers. Moreover, the environmental impacts, such as reduced energy consumption and greenhouse gas emissions, contribute to a more sustainable and eco-friendly distribution process. Thus, stakeholders in the tomato value chain in Nigeria need to focus more on investing in the adoption of innovation such as cold chain logistics innovations and practices for preservations of their products and to improve their decision and planning for effective fresh tomato product routing and scheduling operations and practices in other to serve the customers better and improve the quality-of-service delivery and reduce product waste and losses in the value chain accordingly.

Limitation

The study findings were limited to vehicle routing and scheduling practices in only the tomato value chain along the Kano and Lagos trading corridors in Nigeria and not all service providers were sampled only those directly linked to the study area in Kano (Bagwai, Danbat, Garin Mallam) and Lagos (Agege, Ile Epe, Mile 12 markets) were purposively sampled.

Recommendation for Future Studies

Subsequently, it would be beneficial in the future to focus on finding out the economic implication of vehicle routing and scheduling operations on cold chain logistics business growth and efficiency in other products value chain future studies can focus on exploring the routing and scheduling of other perishable products in the tomato value chains in Nigeria.

Conclusion

This critical survey has shed light on the nexus between cold chain logistics routing and scheduling and the safe distribution of fresh tomatoes in Nigeria. The findings underscore the crucial role of an optimized cold chain system in preserving the quality, freshness, and safety of perishable goods, particularly fresh tomatoes, throughout the distribution process. The study has revealed that Nigeria faces significant challenges in implementing an effective cold chain logistics system. Inadequate infrastructure, limited technological advancements, and a lack of awareness among stakeholders have hindered the development of a robust and efficient cold chain network. However, it is evident that addressing these challenges is essential for reducing post-harvest losses, extending the shelf life of fresh tomatoes, and enhancing market access for farmers.

The exploration the themes and sub-themes, such as routing and scheduling techniques, safety measures and quality assurance, technological innovations, stakeholder collaboration, and economic and environmental impacts, has provided valuable insights into potential solutions and best practices for improving the cold chain logistics system in Nigeria.

In conclusion, this study emphasizes the urgent need for policymakers, industry stakeholders, and researchers to prioritize the development of a robust cold chain logistics system for the safe distribution of fresh tomatoes in Nigeria. By investing in infrastructure, technological advancements, stakeholder collaboration, and capacity building, Nigeria can overcome the existing challenges and realize the potential economic and social benefits associated with an efficient cold chain. It is hoped that the insights and recommendations presented in this study will serve as a valuable resource for driving positive change and enhancing the overall quality and safety of fresh tomato distribution in Nigeria.

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